DEVELOPING AN EFFECTIVE SPATIAL FUEL TREATMENT STRATEGY TO REDUCE WILDFIRE SPREAD AND INTENSITY LEVELS ON THE COLORADO FRONT RANGE

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Final Report

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by

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Introduction

The east slope of the Rocky Mountains in Colorado, or the Colorado Front Range (CFR), is a diverse region providing important natural resources and recreational opportunities for both residents and non-residents. Like much of the West, it is an area experiencing extremely rapid population and economic growth. The CFR begins at the plains, approximately 5,200 feet, and rises to over 14,000 feet in the high mountains along the Continental Divide. Along this elevation gradient climate and vegetation types dramatically change. Ecologists are aware that fire has also been a natural factor in the development of these vegetation communities, but changing fire regimes and other human disturbance such as the introduction on non-native species, including livestock and exotic plant species, have altered the extent and area of the various vegetation types. For example, the suppression of lightning-ignited fire has led to the replacement of fire-resistant species such as ponderosa pine (*Pinus ponderosa*), with less fire-resistant species such as Douglas-fir (*Pseudotsuga menziesii*). In addition, fire suppression has allowed woody fuels to build-up, which may lead to increased fire intensity (Romme and others 2003). Furthermore, in non-forest communities, the introduction of the aggressive annual graminoid cheatgrass (*Bromus tectorum*) into big sagebrush communities has increased fuel loads in some areas, which has resulted in fire frequency changes. Communities that historically burned every 40 to 60 years now may burn 2 or 3 times within 10 years. This alteration of fire frequency does not allow for the reestablishment of big sagebrush, permanently converting these sites to annual grasslands (Howard 1999). The complexity and extent of the CFR, associated with the increasing human population,

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complex vegetation patterns, and changes in fire regimes, challenge managers in their efforts to manage and maintain natural resources and recreational opportunities.

Specifically, managers are confronted with the need to develop appropriate fuel reduction treatments across a complex landscape often with limited spatially and temporally explicit information. As stated previously these landscapes have altered vegetation structure associated with changed fire regimes and/or associated with other human impacts including introduction of non-native species. Managers must be able to identify and prioritize fuel reduction treatments for vegetation types, and the associated mix of vegetation types, that form a high risk of "unnatural" fire impacts, danger to communities and the urban interface with limited budgets. To assist in locating priority areas and the identification of appropriate fuel reduction treatments the U.S. Forest Service, Rocky Mountain Research Station (RMRS) began the development of a Colorado version of the spatially explicit Landscape Dynamic Simulation System (LDSS) SIMPPLLE (derived from Simulating Vegetation Patterns and Processes at Landscape Scales). The College of Forestry and Conservation at The University of Montana, in cooperation with the RMRS developed the successional pathways for forest and non-forest vegetation types found along the CFR. The purpose of this report is to document the procedure and assumptions used to develop the resulting SIMPPLLE pathways.

Our primary focus was the detailed development of non-forest pathways, and the enhancement of the non-forest process logic within SIMPPLLE. We assisted in the development of the forest pathways as well; however, a detailed discussion of both forest and non-forest types is beyond the scope of this paper. While forest type related information is presented, only the system logic for the non-forest types will be described

in detail. Furthermore, simulations for this version of SIMPPLLE were scheduled but not completed in time to be presented in this report.

SIMPPLLE is an "expert knowledge" and literature based LDSS. The knowledge sources for this version of SIMPPLLE were an extensive literature review of related works ranging from forest windthrow dynamics to graminoid successional theory and expert experience. Considering the large ecological amplitude of the CFR, generalizations from specific studies were made in an effort to capture the variability of the study area. A literature review of habitat classification manuals provided the primary species combinations and pathway logic for the various non-forest ecological types. In contrast, the forest pathways were adapted and modified from an existing version of SIMPPLLE, which was based on the vegetative communities found along the east slope of the Rocky Mountains in Montana. When forest pathways were not previously available habitat classifications were consulted. Due to these generalizations it is expected that ecologists in Colorado will find a need to tailor the CFR SIMPPLLE version to their local environment and circumstances. It is the goal of this project however, to capture as much of the ecological trends and phenomena as possible to streamline the simulation process for the Colorado Front.

The remainder of this report is organized into *Methods*, *Results and Discussion*, and *Summary and Conclusions* sections. The *Methods* section documents the procedure by which a landscape is stratified, species identified and organized, and processes (i.e., fire, wildlife browsing, etc.) are identified. The compilation of information provided by an ecological stratification, species mixtures, and system processes result in successional pathways, which are presented in the *Results and Discussion* section. Finally, the

Summary and Conclusions section provides the reader with the lessons learned as a result of this study, and recommendations for improving future versions of CFR SIMPPLLE.

Methods

The following section documents the process employed to build the vegetation successional pathways for the CFR SIMPPLLE LDSS. This version of the system is based on current SIMPPLLE parameters and peer reviewed literature for Colorado and the surrounding area. Because SIMPPLLE is spatially explicit, it requires a "starting point" or a spatially accurate representation of current vegetation. Great emphasis is placed on the study area and accuracy of the vegetation data for that area. In this case the entire CFR was selected as the basis for this version of the LDSS, due to available habitat type information and GIS vegetation inventories for this area. Smaller individual study areas were later divided for simulation interpretation and efficiency.

The process for building the CFR SIMPPLLE vegetation pathways includes: identifying a study area or region, querying GIS vegetation themes of the area to capture dominant species, and establishing ecological stratification (i.e., ecological zones, elevation zones, or habitat type groups, etc.). Habitat type classifications are then consulted to establish species groupings and climax vegetation. The resulting list of climax vegetation from the habitat type manuals is then compared to the dominant species on the GIS layer to select appropriate species combinations and the resulting successional pathways. Next, vegetative responses to natural processes (i.e., response to fire, bark beetle, overstory shading, etc.) were established to provide behavioral consistency throughout the system. Finally, individual species characteristics were researched to provide behavioral context to the derived pathways. Thus, the combination of ecological zone, habitat type, study area species, disturbance response assumptions, and ancillary logic based on species characteristics all contribute to the

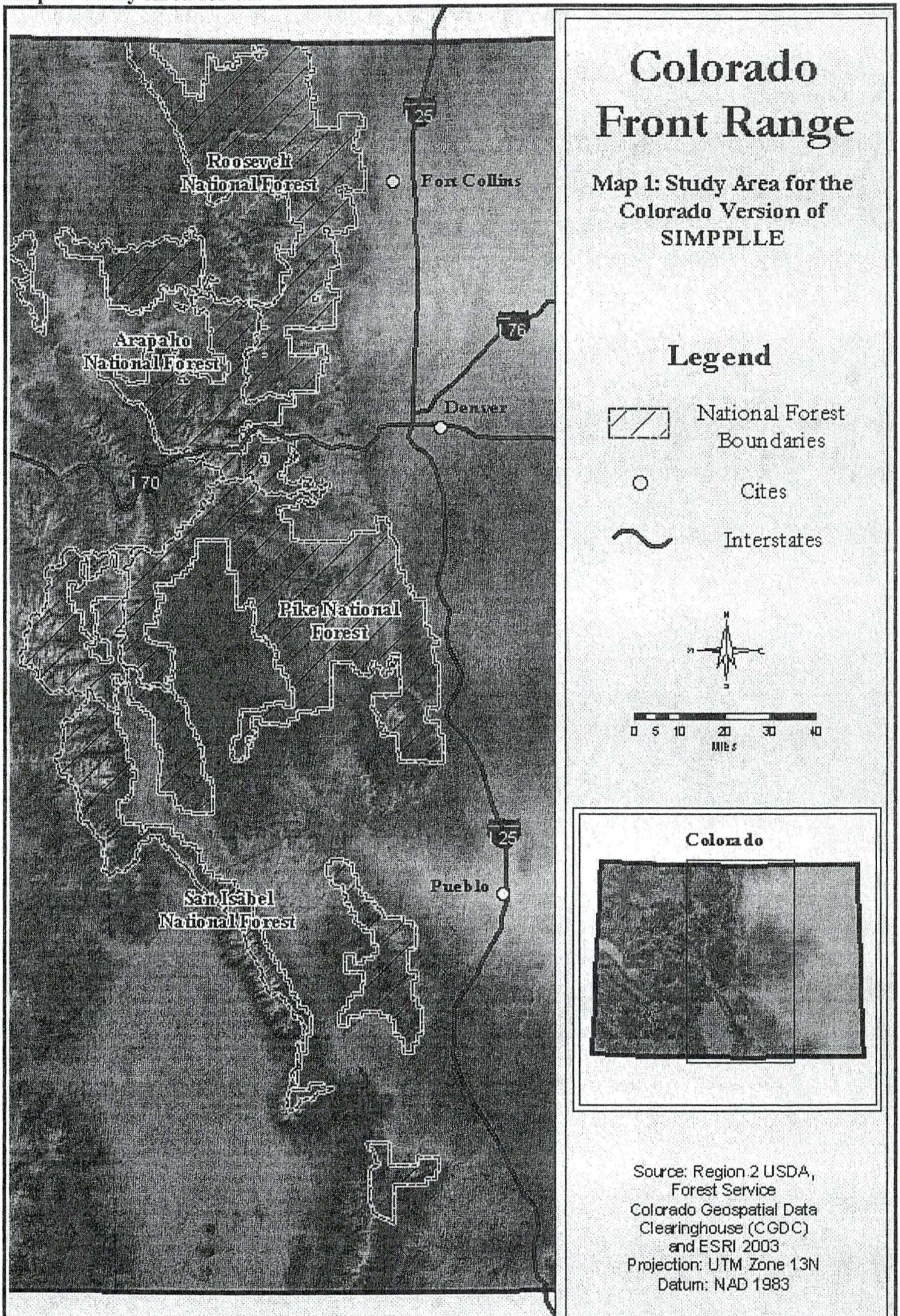
overall vegetative pathway. System pathways are only one component of SIMPPLLE and contain an abstraction of the knowledge necessary to describe community "states" only (Chew 2004).

The methods portion of this report is divided into six subsections. We provide a discussion about the study area, define the ecological stratification, discuss the use of geographic information system (GIS) data, define legal values, document the habitat types and communities found along the CFR, and present the process logic.

Study Area

The Colorado Front Range (east slope) of the Rocky Mountains was chosen as the study area for this project (Map 1). Over 186 miles long, the Colorado Front Range extends from the Laramie and Medicine Bow Ranges in southern Wyoming, south to Arkansas River (Peet 1981). This project includes the Wet and the Sangre de Cristo Mountains of southern Colorado when referring to the Colorado Front Range. Four national forests are encompassed: the Arapaho and Roosevelt National Forests (ARNF) in the north, and the Pike and San Isabel National Forests (PSINF) to the south. Vegetation types along the entire east slope of the Rocky Mountains in Colorado will be considered in the development of SIMPPLLE pathways.

Map 1: Study Area for the Colorado Version of SIMPPLLE.



Ecological Stratification

The selection of ecological or life zones provides a conceptual basis for aggregation knowledge and examining variations in vegetation (Peet 1978). Other version of the LDSS use habitat type groups to ecologically stratify vegetative communities. However, habitat type information was not available from the GIS vegetation coverages for the CFR. As a result, ecological zones were selected as a means of landscape stratification. The use of ecological or life zones in the Rocky Mountains, as a means of communicating ecological ideas, is not new. However, there are several versions of these zones that may lead to confusion (Peet 1978). For example, Ryan and Barrows (1975) use the elevation zones as defined by Kelly (1970). Kelly (1970) reports the plains zone below 6,000 feet, the foothills zone from 6,000 to 8,000 feet, the montane zone from 8,000 to 10,000 feet, the subalpine zone from 10,000 to 11,500 feet and the alpine zone above 11,500 feet. These zone definitions vary from the zones presented by Romme and others (2003). Romme and others (2003) defines the various zones as: plains zone below 5,500 feet, foothills zone from 5,500 to 6,500 feet, montane zone from 6,500 to 8,000 feet (comprised of upper and lower montane), mixed conifer zone from 8,000 to 8,500 feet, the subalpine zone from 8,500 to 11,000 feet, and finally, the alpine zone above 11,000 feet. Possible explanation for the variation in elevation zone definition may include: 1) improved research and vegetation delineation, and 2) differing study area location, which may reflect vegetative transitions from southern latitudes to more northerly latitudes.

The ecological zone definitions of Romme and others (2003) were selected as a template for the CFR version of SIMPPLLE. Romme and others (2003) provides a

recent and complex separation of dominant vegetation type by elevation. The lower montane zone was delineated from 6,500 to 7,500 feet. In addition, the mixed conifer zone was combined with the upper montane zone. The resulting zones for the CFR SIMPPLLE version are as follows: plains (below 5,500 feet), foothills (5,500 to 6,500 feet), lower montane (6,500 to 7,500 feet), upper montane (7,500 to 8,500 feet), subalpine (8,500 to 11,000 feet), and alpine (above 11,000 feet).

Plains

The plains zone (below 5,500 feet) is characterized by short-grass prairie. Depending on local conditions the short-grass prairie may extend well into the foothills zone (Costello 1944, Ryan and Barrows 1975). Dominant vegetation species in this zone includes blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), needle and thread (*Hesperostipa comata*), and as one moves east, buffalo grass (*Buchloe dactyloides*) increases in frequency and importance (Costello 1944, Ryan and Barrows 1975, Peet, 1981).

Foothills

The foothills zone, extending from 5,500 to 6,500 feet, is a very diverse zone characterized by dense shrublands and open ponderosa pine forests. South of Denver, pinyon pine (*Pinus edulis*) and Rocky Mountain juniper (*Juniperus scopulorum*) are commonly found. The understory of Pinyon/Juniper is dominated by the shortgrass species blue grama. In this type, understory condition has a pronounced effect on fire potential. In addition, Gambel oak (*Quercus* gambelii) and mountain mahogany

(*Cercocarpus montanus*) are locally important (Costello 1944, Ryan and Barrows 1975). North of Denver Gambel oak becomes scarce, being replaced by mountain mahogany (Ryan and Barrows 1975, Peet 1978). Big sagebrush species (*Artemisia tridentata*) also begin to appear in northern Colorado (Hess and Alexander 1986). Intensity of fire in shrub communities is dependent on the density and height of the brush (Ryan and Barrows 1975).

Lower Montane

Throughout the lower montane zone (6,500 to 7,500 feet) ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) are the dominant overstory species. In southern Colorado, a well-developed layer of Gambel oak often dominates ponderosa pine forests understory (Peet 1978). In areas lacking Gambel oak, blue grama is the dominant understory species. Throughout other parts of Colorado ponderosa pine forest understory is locally dominated by bunchgrass species such as fescue species (*Festuca* species), mountain muhly (*Muhlenbergia montana*), and wheatgrass species (*Agropyron* species) (Costello 1944, Ryan and Barrows 1975, Peet 1981). Generally, Douglas-fir is restricted to north facing slopes at lower elevations. Important understory species include common juniper (*Juniperus communis*), kinnikinnick (*Arctostaphylos uva-ursi*), fivepetal cliffbush (*Jamesia americana*), and sedge species (*Carex* species) (Ryan and Barrows 1975, Peet 1981).

Ryan and Barrow (1975) found that generally, ponderosa pine is the dominant species below 7,000 feet and Douglas-fir dominates above 8,000 feet. Furthermore, in southern Colorado quaking aspen (*Populus tremuloides*) is the most important

successional species; whereas, lodgepole pine (*Pinus contorta*) becomes the dominant successional species in northern Colorado (Costello 1964, Peet 1978).

Upper Montane

Douglas-fir and combinations of other important conifer species such as lodgepole pine characterize the upper montane zone, ranging from 7,500 to 8,500 feet. Douglas-fir also grows with ponderosa pine in the montane zone. As in the foothills zone, Douglas-fir tends to be more abundant relatively cool, moist sites; whereas, ponderosa pine tends to be more abundant on relatively warm, dry sites within this broad vegetation zone (Ryan and Barrows 1975, Romme and others 2003). In southern Colorado the Douglas-fir dominated montane zone includes locally important mixes of Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and white fir (*Abies concolor*). Further north, important mixed conifers species include lodgepole pine, subalpine fir, and limber pine (*Pinus flexilis*) (Peet 1978, 1981). In the south important understory species include Gamble oak and Arizona fescue (DeVelice and others 1986), whereas, further north common juniper, big sagebrush (*Artemisia tridentata*), and kinnikinnick become important understory species (Peet 1981).

Subalpine

The subalpine zone occurs from about 8,500 to 11,000 feet. Spruce tends to dominate stands in this zone. However, given an excess of 500 years without major disturbance, subalpine fir will likely assume dominance (Peet 1978). In addition, bristlecone pine (*Pinus aristata*) tends to dominate xeric sites in southern Colorado and

limber pine, the same type of sites in the north (Peet 1978, 1981). Again, lodgepole pine communities are wide-spread in the northern half of the state, mainly in the lower half of the subalpine zone and upper montane zones following fire, where in southern Colorado, quaking aspen is the dominant post-fire species. Along the upper subalpine zone spruce-fir forests replace each other following disturbance (Ryan and Barrows 1975, Peet 1978, 1981, Romme and others 2003).

Alpine

The alpine zone, above 11,000 feet, is characterized by tundra, occasional grasses and stunted shrubs due to the short growing season, which fails to support trees (Romme and others 2003). Variation in the designation of the alpine (and other) zones exists. Peet (1978) found the subalpine zone to extend to nearly 12,500 feet in southern Colorado. Therefore, the CFR SIMPPLLE version's alpine zone contains vegetative pathways for species common to the upper extent of the subalpine zone such as Engelmann spruce and subalpine fir.

Geographic Information System

Region 2 USDA Forest Service provided vegetation data in the form of GIS coverages, including digital elevation models (DEM), common vegetation units (CVU), and national forest boundaries. The data was provided as Winzip files and were exported as ESRI ArcInfo (ESRI 2001) interchange files (.e00). All data was projected in Universal Transverse Mercator (UTM), North American Datum (NAD) 1983, zone 13 north. The data was converted from coverage format to feature classes in ArcCatalog

(ESRI 2001). The CVU feature class for the ARNF was queried by hydrologic unit code (6^{th} code) and regrouped into five areas to facilitate computation over such a large extent. Next, zonal statistics were run to calculate the mean elevation of each CVU for the study area. The resulting tables were queried by elevation zone to determine the type, density, structure, and species found within each zone throughout the study area. A species list by elevation zone was then compiled. Summary tables of CVU species by ecological zone are presented in Appendix A.

Legal Values

Legal descriptions, values recognized by SIMPPLLE, for the various vegetation types found in the study area include species name, species code, possible density classes, vegetation structure, and vegetation types. Species name and code were standardized to match the Natural Resources Conservation Service PLANTS database (USDA 2004). Density classes were defined by SIMPPLLE developers and based on current SIMPPLLE versions, while vegetation structure definitions were taken from the CVU GIS data. Density class and stand structure definitions are presented in Tables 1 and 2.

Table 1: Density Class Definitions.

Density Code	Percent Cover
1	0 to 10
2	11 to 40
3	41 to 70
4	70 to 100

Valid processes were selected by SIMPPLLE developers and are presented in Table 3. Tussock moth logic was produced by the SIMPPLLE developers and is not presented in this report.

Table 2: Stand Structure Definitions.

Lifeform	Size	SIMPPLLE Code	Description
Tree	Established Seedling	E	0.0 to 0.9 inches[1]
	Small	SS	1.0 to 4.9 inches[2]
	Medium	MEDIUM	5.0 to 8.9 inches[2]
	Medium-Multistory	MMU	
	Large	LARGE	9.0 to 15.9 inches[2]
	Large-Multistory	LMU	
	Very Large	VERY-LARGE	>16.0 inches[2]
	Very Large-Multistory	VLMU	
Shrubs	Small	SMALL-SH	< 2.5 feet
	Medium	MEDIUM-SH	2.5 to 6.4 feet
	Large	LARGE-SH	>6.5 feet
	Unknown	UNKNOWN	
Graminoids	Clumped	CLUMPED	Bunchgrass growth form
	Uniform	UNIFORM	Other growth forms
Other	Non-stocked	NS	
	Non-forest	NF	

Source: Bowne 2004
[1] Diameter measured at ground level or root collar.
[2] Diameter measured at breast height.

Table 3: CFR Processes[1]

Process	SIMPPLLE Abbreviation
Succession	SUCCESSION
Light severity fire	LSF
Mixed severity fire	MSF
Stand replacing fire	SRF
Ponderosa pine mountain pine beetle	PP-MPB
Lodgepole mountain pine beetle	LP-MPB
Spruce beetle	SPRUCE-BEETLE
Douglas-fir beetle	DF-BEETLE
Pinyon bark beetle	PIED-BB
Light western spruce budworm	LIGHT-WSBW
Severe western spruce budworm	SEVERE-WSBW
Wildlife Browsing	WILDLIFE-BROWSING
Windthrow	WINDTHROW
Wet succession	WET-SUCCESSION
Dry succession	DRY-SUCCESSION

[1] See *Colorado Front Range Processes* for detailed discussion of these processes.

Habitat Types and Associations

Current versions of SIMPPLLE for Region One Forest Service are based on the *Forest Habitat Types of Montana* (Pfister and others 1977). Habitat type classifications

offer logical detailed description of stand ecology and species interactions based on quantitative data. Thus, habitat type classifications for the CFR were used to identify dominant forest, and non-forest types. It should be noted that habitat types with forb dominated understories were not modeled in this version of SIMPPLLE. The omission of forb pathways negates 12 minor habitat types across both northern and southern portions of the CFR. However, it is possible to represent these habitat types with the associated dominant graminoids. The following section summarizes descriptions of habitat types found within the CFR version of SIMPPLLE and the associated pathways for each type. Due to the technical nature of these descriptions, and the use of the scientific species names in the system pathways, this report will use the current accepted scientific name as presented in the PLANTS database (USDA 2004).

Version 2.3 of SIMPPLLE currently does not display vertical lifeform interactions within a stand. Thus, only the dominant overstory cover is represented for each polygon without regard as to the understory structure or species composition. However, the final version of SIMPPLLE for the CFR will contain the logic to display integrated lifeform associations as described in habitat type classifications. As a result, not only will a polygon be designated as a *Pseudotsuga menziesii* stand, it will be labeled as a *Pseudotsuga menziesii-Physocarpus monogynus* type and include important graminoid species. Therefore, this section is included to aid in the completion of lifeform interactions in the final version of the CFR version of SIMPPLLE.

The vast majority of the competitive interactions between species were taken from habitat type classification for the CFR. Northern CFR stand descriptions are taken from *Habitat Type Classification for the Arapaho/Roosevelt National Forest* (Hess and

Alexander 1986) unless otherwise cited; the southern CFR stand descriptions are taken from *A Classification of Forest Habitat Types of Northern New Mexico and Colorado* (DeVelice and others 1986) unless otherwise cited. These works, coupled with that of Peet (1981) provide further reference to the vegetation patterns found along the CFR vegetation. Finally, additional habitat and community types and type descriptions were taken from Alexander (1987) and Costello (1944).

Northern Habitat Types

The following section details habitat types found along the northern extent of the CFR. A complete list of northern habitat types represented by SIMPPLLE pathways is presented in Appendix B.

Juniperus scopulorum Series

Hess and Alexander (1986) documented the *Juniperus scopulorum* series only along northern portion of the CFR on the Roosevelt National Forest (RNF). They describe three habitat types with an environmental gradient from exposed boulder and rock outcroppings on moderate to steep slopes of the foothills and montane zones. Tiedeman and others (1987) further delineated the *Artemisia* associated habitat type to a *Pseudoroegneria spicata* dominated type (table 4), resulting in four possible habitat types for this series. Two pathways represent this habitat type (table 5). The pathways are generalized to represent all of the *J.* species common to the CFR. *Juniperus monosperma* and *J. scopulorum* pathways will remain as such following succession. Other species combination pathways will eventually transition into sites dominated by the secondary

species (i.e., JUSC-PIPO transitions to a PIPO-JUSC stand). These states are present in the Lower Montane zone, while dominating the Plains and Foothill zones.

Table 4: *Juniperus scopulorum* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Juniperus scopulorum	*Cercocarpus montanus*	*Hesperostipa comata*
	Purshia tridentata	*Muhlenbergia montana, Carex rossii*
	Artemisia tridentata	*Achnatherum hymenoides*
	Artemisia tridentata ssp. wyomingensis	*Pseudoroegneria spicata, Bouteloua gracilis*

Source: Hess and Alexander 1986, Tiedeman and others 1987.

Table 5: SIMPPLLE Pathways Associated with *Juniperus scopulorum* Climax Communities.

SIMPPLLE Code	Species Name
JUMO	*Juniperus monosperma*
JUSC2	*Juniperus scopulorum*

Juniperus scopulorum/Cercocarpus montanus type is typically found on steep (45 to 65%) exposed and rocky slopes. This habitat type is the most xeric type in the RNF. *Pinus ponderosa* and *Pseudotsuga menziesii* are sparse and widely scattered throughout the open *J. scopulorum*. *C. montanus* dominates the understory with between 18 and 22% cover. *Hesperostipa comata* is one of the significant graminoids in this type.

Juniperus scopulorum/ Purshia tridentata type is found on dry steep slopes (50 to 75%) in the northern portion of the RNF. *P. ponderosa* and *P. menziesii* are scarce throughout the type dominated by *J. scopulorum* and *P. tridentata* (16 to 20% cover). *Muhlenbergia montana* and *Carex rossii* are important understory species.

Juniperus scopulorum/Artemisia tridentata type is another dry habitat type found on steep (45 to 75%), south-facing slopes in the northern portion of the RNF. *P. ponderosa* and *P. menziesii* are a minor component of this type. *Achnatherum hymenoides* is an important understory species.

Pinus ponderosa Series

The *Pinus ponderosa* series occurs in much of the montane zone along the northern CFR. Hess and Alexander (1986) documented five habitat types (table 6) within this series. Trees of 20 to 24 inch diameter at breast height (dbh) were recorded. Elevation ranges from 6,235 to 8,860 feet on a variety of aspects. This series is associated with more moisture than that of the *Juniperus scopulorum* series. Fourteen pathways having a *P. ponderosa* climax state are represented in the CFR SIMPPLLE version (table 7). This type dominates the Foothills and Lower Montane zones and is represented in the Plains and Upper Montane zones.

Table 6: *Pinus ponderosa* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Pinus ponderosa	*Cercocarpus montanus*	*Carex rossii*
	Purshia tridentata	*Leucopoa kingii, Muhlenbergia montana*
		Muhlenbergia montana
		Leucopoa kingii
		Carex rossii

Source: Hess and Alexander 1986.

Table 7: SIMPPLLE Pathways Associated with *Pinus ponderosa* Climax Communities.

SIMPPLLE Code	Species Name
JUSC2-PIPO	*Juniperus scopulorum-Pinus ponderosa*
PICO-PIPO	*Pinus contorta-Pinus ponderosa*
PIED-PIPO	*Pinus edulis-Pinus ponderosa*
PIFL2-PIPO[1]	*Pinus flexilis-Pinus ponderosa*
PIPO	*Pinus ponderosa*
PIPO-ABCO[1]	*Pinus ponderosa-Abies concolor*
PIPO-JUSC2	*Pinus ponderosa-Juniperus scopulorum*
PIPO-PIAR[1]	*Pinus ponderosa-Pinus aristata*
PIPO-PICO[1]	*Pinus ponderosa-Pinus contorta*
PIPO-PIED	*Pinus ponderosa-Pinus edulis*
PIPO-PIFL2	*Pinus ponderosa-Pinus flexilis*
PIPO-POAN3	*Pinus ponderosa-Populus angustifolia*
PIPO-POTR5	*Pinus ponderosa-Populus tremuloides*
PIPO-PSME[1]	*Pinus ponderosa-Pseudotsuga menziesii*

[1] Only in the Lower Montane, Foothills, and Plains Zones.

Pinus ponderosa/Cercocarpus montanus is the major forest type of the foothills and lower montane zone throughout the RNF. This habitat type occurs on moderate slopes (35 to 60%) with southeast to southwest aspect. This type is one of the driest *P. ponderosa* types and is characterized by the consistent presence and limited reproduction of *P. ponderosa* and the abundance and dominance of *C. montanus* (10 to 17% cover). *Carex rossii* is an important graminoid.

Hess and Alexander (1986) documented the *P. ponderosa/Purshia tridentata* habitat type as a major forest type in the montane zone throughout the northern extent of the RNF. In addition, this dry type is found on gentle (10 to 55%), south-facing slopes. Open *P. ponderosa* stands commonly have *J. scopulorum* and *Pseudotsuga menziesii* growing in association. *P. tridentata* dominates the understory and important graminoids are *Leucopoa kingii* and *Muhlenbergia montanus*.

The *P. ponderosa/M. montanus habitat* type is a minor component in the central and southern extent of the RNF. This habitat type is typically found occupying hilltops and moderate to steep (40 to 65%) south-facing slopes. Again, stands of pines are interspersed with *J. scopulorum* and *P. menziesii* with *M. montanus* comprising 5 to 17% of the understory cover. *Pinus flexilis* may be present. DeVelice and others (1986) recognized this habitat type in northern New Mexico and southern Colorado.

Hess and Alexander (1986) documented the *P. ponderosa/Leucopoa kingii* habitat type as a major forest type throughout the RNF. Typically, this type is found on gentle to moderate (10 to 40%) slopes except for south slopes. *P. menziesii* and *P. flexilis* are scattered throughout a relatively closed and productive *P. ponderosa* overstory. *L. kingii* dominates the graminoid layer with 5 to 16% cover.

The *P. ponderosa/C. rossii* habitat type occurs in small areas, scattered throughout the RNF. The habitat type occupies gentle to moderate (5 to 35%) slopes and various aspects at higher elevations and northerly aspects at lower elevations. These stands are relatively closed and vigorous in which *J. scopulorum* and *P. menziesii* are minor and infrequent stand components. *C. rossii* dominates the understory with 7 to 16% cover; however, *C. montanus* and *Juniperus communis* are consistent throughout the type. A similar type was identified in the Pike National Forest (PNF).

Pseudotsuga menziesii Series

Hess and Alexander (1986) document the *Pseudotsuga menziesii* series exclusively on the steep north to facing slopes in the foothills and montane zones of the ARNF. This series is found in mesic environments from 5,470 to 8,530 feet on north aspects. The *Pinus ponderosa* series is found on the xeric environments of the same elevations. *P. menziesii* is represented by four habitat types (table 8). *P. menziesii* may reach 16 to 20 inch dbh. Seventeen pathways, which have a Pseudotsuga menziesii climax vegetative state, are represented (table 9). These states dominate the Upper and Lower Montane zones and are represented in the Subalpine, Foothills, and Plains zones.

Table 8: *Pseudotsuga menziesii* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
	Physocarpus monogynus	*Leucopoa kingii*
Pseudotsuga menziesii	*Jamesia americana*	*Carex rossii*
		Carex geyeri
		Carex rossii

Source: Hess and Alexander 1986.

Table 9: SIMPPLLE Pathways Associated with *Pseudotsuga menziesii* Climax Communities.

SIMPPLLE Code	Species Name
JUSC2-PSME	*Juniperus scopulorum-Pseudotsuga menziesii*
PICO-PSME	*Pinus contorta-Pseudotsuga menziesii*
PIED-PSME	*Pinus edulis-Pseudotsuga menziesii*
PIFL2-PSME	*Pinus flexilis-Pseudotsuga menziesii*
PIPO-PSME[1]	*Pinus ponderosa-Pseudotsuga menziesii*
POAN3-PSME	*Populus angustifolia-Pseudotsuga menziesii*
POTR5-PSME	*Populus tremuloides-Pseudotsuga menziesii*
PSME	*Pseudotsuga menziesii*
PSME-ABCO	*Pseudotsuga menziesii-Abies concolor*
PSME-JUSC2	*Pseudotsuga menziesii-Juniperus scopulorum*
PSME-PIAR	*Pseudotsuga menziesii-Pinus aristata*
PSME-PICO	*Pseudotsuga menziesii-Pinus contorta*
PSME-PIED	*Pseudotsuga menziesii-Pinus edulis*
PSME-PIFL2	*Pseudotsuga menziesii-Pinus flexilis*
PSME-PIPO[1]	*Pseudotsuga menziesii-Pinus ponderosa*
PSME-PIPU	*Pseudotsuga menziesii-Picea pungens*
PSME-POTR5	*Pseudotsuga menziesii-Populus tremuloides*

[1] Only found in the Upper Montane Zone.

The *P. menziesii/Carex rossii* habitat type is a widely distributed but relatively minor type occurring at low elevations and on steep (45 to 60%) north to northwest slopes. This is the driest type in the *P. menziesii* series. Seral tree associates include *P. ponderosa* and *Juniperus scopulorum*. The shrub layer consists of few *Juniperus communis* and *Physocarpus monogynus*. *Carex rossii* is the dominant graminoid with 4 to 5% average cover.

The *P. menziesii/Carex geyeri* habitat type is a minor habitat type located west of the Continental Divide on the Arapaho National Forest (ANF). This type is found on very steep (45 to 80%) north to northwest-facing slopes. This type is wetter than the *P. menziesii/C. rossii* type found along the CFR of the RNF. The canopy in this type is relatively closed with *C. geyeri* comprising 26 to 42% of the understory cover. Occasional *J. scopulorum* and *Symphoricarpos* species are found throughout the type.

Hess and Alexander (1986) document a *P. menziesii/P. monogynus* habitat type as a common and widely distributed type east of the Continental Divide. This type occurs

on wetter sites than the *Carex* dominated habitat type on steep (55 to 65%) north to northwest-facing slopes. *P. ponderosa* and *J. scopulorum* are the seral tree species, with *Jamesia americana, J. communis,* and *Symphoricarpos* species as associated shrubs. *Physocarpus monogynus* comprises 14 to 35% of the understory cover. *Leucopoa kingii* is an important understory species.

The *P. menziesii/J. americana* habitat type has a broad distribution but is not locally abundant in the RNF. This type is found on steep to very steep (55 to 75%) north to northwest-facing slopes. *Pinus ponderosa* and *J. scopulorum* are the seral tree associates. *J. americana* makes up 17 to 29% of the understory cover, with *Acer glabrum, J. communis,* and *P. monogynus* as associated shrubs. *C. rossii* is an important graminoid in this type.

Populus tremuloides Series

Hess and Alexander (1986) found the *Populus tremuloides* series to occur in both the montane and subalpine forest zones throughout the ARNF. The series occupies mesic sites with a high water table. *P. tremuloides* series is found at elevations from 8,040 to 9,680 feet on both sides of the Continental Divide with the greatest occurrences in the northwestern extent of the ANF and the northern extent of the RNF. While three habitat types were documented by Hess and Alexander (1986) with trees to 16 to 20 inch dbh only two types were included in the CFR SIMPPLLE version (table 10). Only one pathway represents a climax *P. tremuloides* state (table 11). It is assumed that if the GIS coverage lists associated tree species with *P. tremuloides* the vegetation is in a seral stage and the associated tree species will eventually develop a climax dominant forest.

Table 10: ***Populus tremuloides*** **Habitat Type Representation in the CFR SIMPPLLE Version.**

Overstory	Shrubs	Grasses
Populus tremuloides		*Festuca thurberi* *Carex geyeri*

Source: Hess and Alexander 1986.

Table 11: SIMPPLLE Pathways Associated with ***Populus tremuloides*** **Climax Communities.**

SIMPPLLE Code	Species Name
POTR5	*Populus tremuloides*

The successional role of *P. tremuloides* is not clear. Mueggler (1985a, as cited in Hess and Alexander 1986) contends that *P. tremuloides* may fill the role of both climax and seral species in the Rocky Mountains. Succession of *P. tremuloides* stands to conifer stands is apparently slowed significantly by soil changes occurring as the result of the deciduous species site occupation. It appears the origin of seral and climax *P. tremuloides* stands may be the result of repeated stand-replacing fires in coniferous forests.

P. tremuloides forests are even-aged as the result of sprouting following disturbance or in a stand where old trees die over a short time period. In uneven-aged stands sprouting provides enough young trees to perpetuate the stand indefinitely. Light flashy surface fires may promote a two story stand were sprouting is stimulated but the overstory trees were not destroyed.

The *P. tremuloides/Festuca thurberi* habitat type is the driest of the *P. tremuloides* types. It is found on both sides of the Continental Divide, but is more common on the ANF. This type is often found adjacent to the *Artemisia* dominated shrublands and on moderate (20 to 30%) south-facing slopes or ridge line depressions were snow accumulates. *F. thurberi* is the dominant understory species with 36 to 45%

cover. Associated shrubs include *Amelanchier alnifolia, Artemisia tridentata,* and *Symphoricarpos* species.

Hess and Alexander (1986) documented the *P. tremuloides/Carex geyeri* habitat type as widely distributed throughout the ARNF. This type, while most conspicuous in the northern RNF, occurs on moderate to steep (15 to 60%) south-facing slopes. *C. geyeri* makes up 28 to 42% of the understory. *Juniperus communis* is an important understory associate.

Pinus flexilis Series

Hess and Alexander (1986) define the *Pinus flexilis* series as having broad elevation gradient, but a narrow environmental gradient. Habitat types in this series are found along very rocky, windswept locations in the montane and subalpine zones of the ARNF at elevations from 8,450 to 11,450 feet. While three habitat types were documented by Hess and Alexander (1986) only two types were included in the CFR SIMPPLLE version (table 12). *P. flexilis* was represented by sizes of 20 to 24 inch dbh. Three pathways with *P. flexilis* climax vegetation are represented in the CFR version of SIMPPLLE (table 13).

Table 12: *Pinus flexilis* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Pinus flexilis	*Juniperus communis*	*Calamagrostis purpurascens, Carex rossii*
		Calamagrostis purpurascens

Source: Hess and Alexander 1986.

Table 13: SIMPPLLE Pathways Associated with *Pinus flexilis* Climax Communities.

SIMPPLLE Code	Species Name
PICO-PIFL2	*Pinus contorta-Pinus flexilis*
PIFL2-PICO	*Pinus flexilis-Pinus contorta*
PIFL2-POTR5	*Pinus flexilis-Populus tremuloides*

The *P. flexilis/Juniperus communis* habitat type is a minor component on the ARNF. This type is found on ridge tops and moderate (15 to 40%) upper slopes. The open tree canopy is dominated by *P. flexilis*. *Pinus ponderosa* (lower elevations), and *Pinus contorta* (higher elevations) are common overstory associates. The understory is dominated by *J. communis* with an average cover from 7 to 25%. *Arctostaphylos uva-ursi* is an important shrub in this type. Important graminoids include *Calamagrostis purpurascens* and *Carex rossii*.

Hess and Alexander (1986) documented the *P. flexilis/C. purpurascens* habitat type as a widely distributed type on the ARNF. This type is locally abundant along the CFR on rocky ridge tops and moderate (10 to 35%) upper slopes of various aspects. Open *P. flexilis* forests with an understory of *C. purpurascens* (9 to 20% cover) typify this habitat type. Isolated *P. engelmannii* and *P. contorta* occur in the overstory. *C. rossii* is another important graminoid.

Pinus contorta Series

Hess and Alexander (1986) document the *Pinus contorta* series as a major component of the ARNF in the upper montane and lower subalpine forest zones with elevations ranging from 8,400 to 10,500 feet. This series, represented by four habitat types (table 14), has trees to 16 to 20 inch dbh. It is assumed that *P. contorta* plays a predominantly seral or subclimax role in this version of SIMPPLE. Therefore, *P. contorta* is the climax species in only one pathway (table 15). The remaining *P. contorta* pathways transition into the associated dominant species.

Table 14: *Pinus contorta* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
	Juniperus communis	*Calamagrostis purpurascens, Carex rossii*
Pinus contorta	*Shepherdia canadensis*	*Carex geyeri, Carex rossii*
	Vaccinium scoparium	*Carex geyeri*
		Carex geyeri

Source: Hess and Alexander 1986.

Table 15: SIMPPLLE Pathways Associated with *Pinus contorta* Climax Communities.

SIMPPLLE Code	Species Name
PICO-POTR5	*Pinus contorta-Populus tremuloides*

Widespread and repeated fire is often a natural component in the development of this series throughout the ARNF. While it is still unclear whether *P. contorta* is a seral or climax species, many now believe it is a climax or subclimax species in certain situations. Moir (1969, as cited in Hess and Alexander 1986) documented climax *P. contorta* stands within the upper montane zone of the CFR. On the ARNF *P. contorta* was seldom found in *Pseudotsuga menziesii* or *Populus tremuloides* forest; it was a common seral species in *Picea engelmannii-Abies lasiocarpa* forest however. Seral *P. contorta* is more likely to be even-aged with a high proportion of serotinous cones, while the climax *P. contorta* forests tended to have several age classes and a lower proportion of serotinous cones (Hess and Alexander 1986).

The *P. contorta/Juniperus communis* habitat type is the driest type of this series and is found commonly along the CFR on gentle to moderate (10 to 45%) slopes of various aspects. Characteristically, this type is dominated by *P. contorta* with the occasional occurrence of *P. menziesii* and *P. engelmannii*. *J. communis* dominates the understory with 9 to 15% cover. *Arctostaphylos uva-ursi* is another important shrub.

The scarce herbaceous understory often contains *Calamagrostis purpurascens* and *Carex rossii*.

The *P. contorta/Shepherdia canadensis* habitat type is a major component of the ANF. This type occurs on gentle to moderate (10 to 40%) slopes among various aspects. No other tree species are found in common association with *P. contorta*. *A. uva-ursi, J. communis,* and *Vaccinium scoparium* are all found in association with the dominant shrub *S. canadensis* (31 to 47% cover). Important graminoids are *Carex geyeri* and *C. rossii*.

Hess and Alexander (1986) documented the *P. contorta/V. scoparium* habitat type as reaching the upper extent of the attitudinal limits of *P. contorta* series. While occurring on the ARNF, this type is more common to the RNF and is found on moderate to steep (15 to 45%) cold, dry south-facing slopes. Occasionally *P. engelmannii* and *A. lasiocarpa* are found in the overstory. *V. scoparium* dominates the understory with 30 to 47% cover and is associated with *J. communis*. *C. geyeri* is an important herbaceous species in this type.

The *P. contorta/C. geyeri* habitat type documented by Hess and Alexander (1986) occurs at the lower elevations with in the range of the *P. contorta* series. However, this type is wetter than the *P. contorta/J. communis* type. This type is found commonly on the west side of the Continental Divide on level to gentle (0 to 10%) north-facing slopes. *C. geyeri* is the dominant understory species with 22 to 41% cover, the shrub layer is scarce and there are no other associated trees.

Picea engelmannii Series

Hess and Alexander (1986) document this series as a minor type in the ARNF, but occurring throughout the area. The series is found in the subalpine zone from elevations of 10,820 to 11,320 feet. This series is characterized by the absence or weak reproduction of *Abies lasiocarpa* in the stands. One habitat type was reported (table 16) with tree sizes of 16 to 20 inch dbh. The CFR SIMPPLLE version does not capture this habitat type because of a forb dominated understory. Nine pathways exist which culminate in a *P. engelmannii* dominated state (table 17), however, the *P. engelmannii* pathway later transitions to a *P. engelmannii-A. lasiocarpa* dominated stand. Thus, due to the limited distribution of this habitat type, it is assumed all *P. engelmannii* stands are eventually colonized by the co-climax species *A. lasiocarpa* and the reader is referred to the description for the *A. lasiocarpa* series for further discussion of these species and their habitat types.

Table 16: *Picea engelmannii* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Picea engelmannii		*Calamagrostis purpurascens*

Source: Hess and Alexander 1986.

Table 17: SIMPPLLE Pathways Associated with *Picea engelmannii* Climax Communities.

SIMPPLLE Code	Species Name
PICO[1]	*Pinus contorta*
PICO-PIEN	*Pinus contorta-Picea engelmannii*
PIEN-PIAR	*Picea engelmannii-Pinus aristata*
PIEN-PICO	*Picea engelmannii-Pinus contorta*
PIEN-PIFL2	*Picea engelmannii-Pinus flexilis*
PIEN-POTR5	*Picea engelmannii-Populus tremuloides*
PIFL2-PIEN	*Pinus flexilis-Picea engelmannii*
POTR5-PIEN	*Populus tremuloides-Picea engelmannii*
PSME-PIEN	*Pseudotsuga menziesii-Picea engelmannii*

[1] Subalpine zone only.

The *P. engelmannii/Trifolium dasyphyllum* habitat type defined by Hess and Alexander (1986) is not modeled in the CFR SIMPPLLE version, however, it is possible

to have a *P. engelmannii* dominant overstory with *Calamagrostis purpurascens* as the dominant understory species. This is a generalized representation of the Hess and Alexander (1986) habitat type. In the *P. engelmannii/T. dasyphyllum* habitat type *A. lasiocarpa* and *Pinus aristata* are minor components. The shrub layer is almost nonexistent with the forb *T. dasyphyllum* dominating the understory.

Abies lasiocarpa Series

The *Abies lasiocarpa* series documented by Hess and Alexander (1986) is a major type in the high, cold coniferous forests of the ARNF. This series is dominated by *A. lasiocarpa* and *Picea engelmannii* in the subalpine zone, and is found on all aspects at elevations from 9,020 to 11,320 feet. It has also been reported as low as 8,000 feet and as high as 11,500 feet in the central Rocky Mountains. Hess and Alexander (1986) note that the habitat types in this series all list *A. lasiocarpa* as the climax dominant to be consistent with habitat types identified elsewhere. However, *P. engelmannii* is a co-climax dominant with little evidence of its replacement by *A. lasiocarpa* unless severe spruce beetle infestation removes *P. engelmannii. Pinus contorta* and *Populus tremuloides* are often present as seral species. Four habitat types are listed within the series; however, only three types were identified for use in the CFR SIMPPLLE version (table 18). Tree sizes of 28 to 32 inch dbh were recorded. Nine pathways culminate in *A. lasiocarpa* climax vegetation (table 19).

Table 18: *Abies lasiocarpa* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
	Vaccinium scoparium	*Carex rossii, Calamagrostis canadensis*
Abies lasiocarpa		*Carex geyeri*
		Calamagrostis canadensis

Source: Hess and Alexander 1986.

Table 19: SIMPPLLE Pathways Associated with *Abies lasiocarpa* Climax Communities.

SIMPPLLE Code	Species Name
ABLA	*Abies lasiocarpa*
ABLA-PIAR	*Abies lasiocarpa-Pinus aristata*
ABLA-PICO	*Abies lasiocarpa-Pinus contorta*
ABLA-PIEN[1]	*Abies lasiocarpa-Picea engelmannii*
ABLA-PIFL2	*Abies lasiocarpa-Pinus flexilis*
PICO-ABLA	*Pinus contorta-Abies lasiocarpa*
PIEN[1]	*Picea engelmannii*
PIEN-ABLA[1]	*Picea engelmannii-Abies lasiocarpa*
POTR5-ABLA	*Populus tremuloides-Abies lasiocarpa*

[1] Co-climax association.

The *A. lasiocarpa/Carex geyeri* habitat type is found west of the Continental Divide on gentle (10 to 15%) west-facing slopes at low elevations on the ANF. This type is also found at higher elevations on gentle to moderate (10 to 30%) south-facing slopes. *C. geyeri* (17 to 27% cover) is the dominant understory species. *P. engelmannii* is a co-climax species in this type with *P. contorta* and *P. tremuloides* as important seral species.

Hess and Alexander (1986) documented the *A. lasiocarpa/V. scoparium* habitat type as a major type occurring from level to very steep (0 to 70%) slopes and all aspects. This type is typified by the overstory dominance of *A. lasiocarpa/P. engelmannii* and an understory dominance of *V. scoparium* and *Vaccinium myrtillus* with over 50% cover. *Calamagrostis canadensis* and *Carex rossii* are the most common herbaceous species found in this type.

The *A. lasiocarpa/C. canadensis* habitat type is the coldest and wettest environment in the series. This minor type is found throughout the ARNF occurring in bottomlands on benches adjacent to streams (0 to 10% slopes). *A. lasiocarpa* and *P. engelmannii* dominate the open-canopy with *C. canadensis* (25 to 45% cover) the dominant understory species. *V. scoparium* and *V. myrtillus* are important shrub species.

Pinus aristata Series

Hess and Alexander (1986) document the *Pinus aristata* series as a minor component of the ARNF occurring just below timberline at elevations from 11,240 to 11,645 feet. One habitat type was documented with tree sizes greater than 32-inch dbh. The CFR SIMPPLLE version does not represent the habitat type due to the forb dominance. However, SIMPPLLE recognizes *P. aristata* in the moderately closed stand structure indicated by Hess and Alexander (1986) with important graminoids including *Calamagrostis purpurascens* and *Carex foenea* (table 20). It was assumed that if *P. aristata* was listed first in the GIS coverage the site potential was a *P. aristata* type, thus there are 10 pathways that have a *P. aristata* climax state (table 21).

Table 20: *Pinus aristata* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Pinus aristata		*Calamagrostis purpurascens, Carex foenea*

Source: Hess and Alexander 1986.

Table 21: SIMPPLLE Pathways Associated with *Pinus aristata* Climax Communities.

SIMPPLLE Code	Species Name
PIAR	*Pinus aristata*
PIAR-PICO	*Pinus aristata-Pinus contorta*
PIAR-PIEN	*Pinus aristata-Picea engelmannii*
PIAR-PIFL2	*Pinus aristata-Pinus flexilis*
PIAR-PIPO	*Pinus aristata-Pinus ponderosa*
PIAR-POTR5	*Pinus aristata-Populus tremuloides*
PIAR-PSME	*Pinus aristata-Pseudotsuga menziesii*
PIED-PIAR	*Pinus edulis-Pinus aristata*
PIFL2-PIAR	*Pinus flexilis-Pinus aristata*
POTR5-PIAR	*Populus tremuloides-Pinus aristata*

Populus angustifolia Series

Hess and Alexander documented the *Populus angustifolia* series in the upper foothills and lower montane zones along the CFR. This series occurs along riparian corridors and floodplains from 6,560 to 7,790 feet. This series has one habitat type (table

22) and tree sizes from 16 to 20 inch dbh were recorded. Three pathways exhibit a *P. angustifolia* climax state (table 23).

Table 22: *Pinus angustifolia* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Populus angustifolia	*Salix* species, *Acer glabrum*	*Calamagrostis canadensis*

Source: Hess and Alexander 1986, Peet 1981, Alexander 1987.

Table 23: SIMPPLLE Pathways Associated with *Pinus angustifolia* Climax Communities.

SIMPPLLE Code	Species Name
POAN3	*Populus angustifolia*
POAN3-POTR5	*Populus angustifolia-Populus tremuloides*
POTR5-POAN3	*Populus tremuloides-Populus angustifolia*

The *P. angustifolia/Salix exigua* habitat type is characterized by gentle terrain, which is subject to spring flooding. While *S. exigua* dominates the understory (8 to 19% cover), the SIMPPLLE version of the CFR uses *Salix* species to capture the range of different willows in the type. Minor trees within the type include *Juniperus scopulorum, Picea pungens, Pinus ponderosa,* and *Populus tremuloides*. Shrubs within this type include *Salix* species, *Alnus tenuifolia,* and *Betula occidentalis* among others. Major graminoid species include *Calamagrostis canadensis* and *Carex species*.

Picea pungens Series

The *Picea pungens* series documented by Hess and Alexander (1986) occurs in riparian areas at elevations ranging from 7,465 to 8,860 feet along the CFR. One habitat type was documented for this type with tree sizes to individuals greater than 32-inch dbh.

Table 24: *Picea pungens* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Picea pungens		*Carex foenea, Calamagrostis canadensis, Poa pratensis*

Source: Hess and Alexander 1986.

Table 25: SIMPPLLE Pathways Associated with *Picea pungens* Climax Communities.

SIMPPLLE Code	Species Name
PIPO-PIPU	*Pinus ponderosa-Picea pungens*
PIPU	*Picea pungens*
PIPU-PIPO	*Picea pungens-Pinus ponderosa*
PIPU-POAN3	*Picea pungens-Populus angustifolia*
PIPU-POTR5	*Picea pungens-Populus tremuloides*
PIPU-PSME	*Picea pungens-Pseudotsuga menziesii*
POAN3-PIPU	*Populus angustifolia-Picea pungens*
POTR5-PIPU	*Populus tremuloides-Picea pungens*

Hess and Alexander (1986) defined the *P. pungens/Arnica cordifolia* habitat type (1986). Because forbs were not included, the CFR SIMPPLLE version of this minor habitat type, occurring on nearly level (0 to 10% slope) benches adjacent to streams, uses a representative set of pathways to capture this type. Associated tree species include *Abies lasiocarpa, Pinus contorta, Populus tremuloides,* and *Pseudotsuga menziesii.* Shrubs are represented by sparse coverage of *Juniperus communis* and the understory includes: *Calamagrostis canadensis, Carex foenea,* and with moderate to high long-term grazing *Poa pratensis.*

Southern Habitat types

The following section details the habitat types found along the southern extent of the CFR. A complete list of southern habitat types represented by SIMPPLLE pathways is presented in Appendix C.

Abies concolor Series

The *Abies concolor* series documented by DeVelice and others (1986) is found at mid-elevations and is the most widespread mixed conifer series with up to seven overstory species present in a stand. *A. concolor, Abies lasiocarpa, Picea engelmannii,*

Picea pungens, Pinus flexilis, Pinus ponderosa, and *Pseudotsuga menziesii* are all found as overstory associates in the *A. concolor* series. The appearance and proportion of each species is dependent on the moisture-temperature relationship of the site. Early seral communities on mesic sites are dominated by *Populus tremuloides,* with *Quercus gambelii* dominating xeric sites. This series is found at elevations from 7,900 to 10,200 feet from cold moist sites to warm dry sites. Seven habitat types were identified for this series, however, the CFR SIMPPLLE version only addresses five habitat types (table 26). Due to the high shade tolerance of this species a majority of the pathways containing *A. concolor* result in *A. concolor* climax stands (table 27).

Table 26: *Abies concolor* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
	Vaccinium myrtillus	*Carex rossii*
	Acer glabrum	*Carex rossii, Poa fendleriana*
Abies concolor	*Arctostaphylos uva-ursi*	*Muhlenbergia montana, Poa fendleriana*
	Quercus gambelii	*Carex rossii, Poa fendleriana*
		Festuca arizonica, Danthonia parryi

Source: DeVelice and others 1986.

Table 27: SIMPPLLE Pathways Associated with *Abies concolor* Climax Communities.

SIMPPLLE Code	Species Name
ABCO	*Abies concolor*
ABCO-PIEN	*Abies concolor-Picea engelmannii*
ABCO-PIFL2	*Abies concolor-Pinus flexilis*
ABCO-POTR5	*Abies concolor-Populus tremuloides*
ABCO-PSME	*Abies concolor-Pseudotsuga menziesii*
PIFL2-ABCO	*Pinus flexilis-Abies concolor*
PIPO-ABCO[1]	*Pinus ponderosa-Abies concolor*
POTR5-ABCO	*Populus tremuloides-Abies concolor*
PSME-ABCO[1]	*Pseudotsuga menziesii-Abies concolor*

[1] Subalpine and Upper Montane zones

The *A. concolor/Vaccinium myrtillus* habitat type is a minor type in this series. This type occurs from 8,500 to 9,200 feet on steep, cold, northerly slopes below the *A. lasiocarpa/P. engelmannii* series. This type is comprised of highly mixed overstory in

which any of the several species listed above may be present. Understory vegetation is dominated by *V. myrtillus* (22% mean plot cover[1]) with *Acer glabrum, Amelanchier alnifolia, Arctostaphylos uva-ursi,* and *Symphoricarpos* species all found within this type. *Carex rossii* is an important graminoid.

The *A. concolor/A. glabrum* habitat type is a common type throughout the area, showing a wide ecological range from elevations of 8,200 to 9,850 feet across all slopes and aspects. *A. concolor* and *P. menziesii* co-dominate these stands with locally important pockets of *P. pungens, P. flexilis, A. lasiocarpa,* and *P. engelmannii.* The shrub layer is dominated by *A. glabrum* (14% mean plot cover) with *A. glabrum, A. alnifolia,* and *J. americana. C. rossii* and *Poa fendleriana* are the most common graminoid species.

DeVelice and others (1986) describe the *A. concolor/A. uva-ursi* habitat type as one of minor importance, but with common occurrence throughout southern Colorado. The overstory is characterized by *A. concolor* with both *P. menziesii* and *P. ponderosa* as major seral associates. The understory is dominated by *A. uva-ursi* (24% mean plot cover), with graminoids such as *Muhlenbergia montana* and *P. fendleriana*, but rarely with 5% cover.

The *A. concolor/Q. gambelii* habitat type is the most widespread habitat type in the mixed conifer series. This type occurs on all aspects from elevations of 7,900 to 9,500 feet from gentle to steep slopes. Overstory vegetation is dominated by *A. concolor* and *P. menziesii.* Major seral species include *P. flexilis, P. ponderosa,* and *P. tremuloides. Q. gambelii* dominates the understory with an average of 22% plot cover,

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[1] Sampling methods followed those of Moir and Ludwig (1983). Reconnaissance and analytical plots were included in the study to check and calibrate the accuracy of shrub and herb cover.

but at times *Q. gambelii* will form thickets. Associated graminoids are *C. rossii* and *P. fendleriana.*

The *A. concolor/Festuca arizonica* habitat is a minor type in which *A. concolor* and *P. menziesii* co-dominate the site. It is found along moderate to steep slopes on all aspects from 8,200 feet to 10,200 feet. *P. ponderosa* is an important seral or minor climax species. *Danthonia parryi, F. arizonica,* and *M. montana* are important understory species.

Pinus ponderosa Series

DeVelice and others (1986) documented the *Pinus ponderosa* series as one of low-elevation types between 5,900 and 9,500 feet. On the more mesic sites in this series *P. menziesii* occurs as a minor component. *Pinus edulis, Juniperus scopulorum,* and *Q. gambelii are* important on warm dry sites. *Q. gambelii* is the dominant seral species in this series. Eight habitat types were identified in this series, however, SIMPPLLE modeled six of the documented habitat types (table 28). The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 28: *Pinus ponderosa* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Pinus ponderosa	*Arctostaphylos uva-ursi*	*Festuca arizonica, Muhlenbergia montana*
	Quercus gambelii	*Carex geyeri, Festuca arizonica*
		Festuca arizonica
		Muhlenbergia montana
		Bouteloua gracilis

Source: DeVelice and others 1986.

The *P. ponderosa/Arctostaphylos uva-ursi* habitat type is a minor type found along the lower slopes and ridges at elevations of 7,700 to 9,200 feet along all exposures

and slopes. *P. ponderosa* dominates the overstory with an occasional *P. menziesii* in the stand. The understory is dominated by *A. uva-ursi* with cover ranging from 30 to 70%. *Carex rossii, Festuca arizonica,* and *Muhlenbergia montana* are important understory species with low coverages.

The *P. ponderosa/F. arizonica* is widespread throughout the southern Rocky Mountains. This type is found at elevations of 7,200 to 9,500 feet on all aspects and slopes. *P. menziesii* is found in some stands. The understory is dominated by graminoids with a minor shrub component. This habitat type is separated into three phases based on the presence of *F. arizonica* (13% mean plot cover), *Danthonia parryi* (17% mean plot cover), and *Bouteloua gracilis* (less than 10% mean plot cover).

The *P. ponderosa/Q. gambelii* habitat type is found across considerable topographic variation at elevations ranging from 6,550 to 9,200 feet on gentle to very steep slopes. *P. edulis* and *J. scopulorum* are absent. *Q. gambelii* dominates the understory with approximately 27% mean plot cover, however, it sometime forms dense thickets. The most common understory species are *Cercocarpus montanus, B. gracilis, C. rossii, F. arizonica,* and *P. fendleriana.* This habitat type is also subdivided into three phases- the *F. arizonica, Q. gambelii,* and *P. edulis* phases depending on species occurrence and regeneration.

The *P. ponderosa/M. montana* habitat type is found on gently sloping ridges, mesa tops, and benches from 7,550 to 8,500 feet. *P. ponderosa* consistently dominates this type with occasional occurrence of *Juniperus* species and *P. edulis. Q. gambelii* exhibits low cover (5% of less) with the understory dominated by *M. montana* and *P. fendleriana* (less than 10% mean plot cover).

The *P. ponderosa/B. gracilis* habitat type is found on all aspects from elevations of 6,250 to 8,550 feet on gentle to steep lower slopes. *P. ponderosa* and *P. edulis* co-dominate the overstory with *J. scopulorum* and *Juniperus monosperma* frequently important. *B. gracilis* dominates the understory (less than 10% mean plot cover), however, *M. montana* and *P. fendleriana* are often represented. This type commonly transitions into pinyon-juniper woodlands or sagebrush meadows.

The *P. ponderosa/ Achnatherum hymenoides* habitat type is uncommon in southern Colorado. This type appears on stabilized sand dunes where *P. ponderosa* and *J. monosperma* dominate the open canopy stands, and *A. hymenoides* dominates the herbaceous layer.

The CFR version of SIMPPLLE models a possible *P. ponderosa/Poa pratensis* community. This community is the result of past heavy grazing. In some cases, past disturbance in these sites may have changed the site potential in such a way as to reduce the establishment of native vegetation.

Pseudotsuga menziesii Series

The *Pseudotsuga menziesii* series documented by DeVelice and others (1986) are a minor type in the southern Rocky Mountains and only two habitat types were identified (table 29). The more shade tolerant *Abies concolor* is often present in many of the *P. menziesii* stands but is considered the climax species. The *P. menziesii* series is found on steep slopes from 6,550 to 9,500 feet. Early succession tree species are principally *Populus tremuloides* and *Quercus gambelii*. The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 29: *Pseudotsuga menziesii* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Pseudotsuga menziesii	*Quercus gambelii*	*Poa fendleriana, Carex geyeri* *Festuca arizonica*

Source: DeVelice and others 1986.

The *P. menziesii/Festuca arizonica* habitat type is a minor type of southern Colorado found on steep southerly exposures from 8,850 to 9,500 feet. All coniferous species of the mixed forests may be present except *Abies concolor. F. arizonica* is the dominant understory species (11% mean plot cover). *Arctostaphylos uva-ursi* and *Muhlenbergia montana* are often found in this type.

The *P. menziesii/Q. gambelii* habitat type documented by DeVelice and others (1986) is separated into two phases. The first is *F. arizonica* (5% mean plot cover) is distinctive. A second phase is when *Q. gambelii* dominates the understory with 35% mean plot cover. *Poa fendleriana* and *Carex geyeri* are occasionally important in the *Q. gambelii* phase of this type. This type is typically found on all aspects and moderate to steep slopes from elevations of 6,550 to 9,200 feet.

Populus tremuloides Series

DeVelice and others (1986) did not investigate stands dominated by *Populus tremuloides* because of the considerable disagreement among ecologists regarding the successional status of the species. As indicated earlier, ecologists are undecided as to whether *P. tremuloides* is a seral or climax species, however, many now think that depending on environmental conditions *P. tremuloides* is both a seral and climax species (Mueggler 1985a, as cited in Hess and Alexander 1986). However, Peet (1978) goes on states that *P. tremuloides* along with *Pinus contorta* play the primary role in forests of the

southern Rocky Mountains. *P. tremuloides* dominates the southern mid-elevation forests with *P. contorta* increasing in importance as one reaches 39° north latitude.

Despite the uncertainty as to the successional role of *P. tremuloides*, Alexander (1987) documents several habitat and community types[2] found on the PSINF of Colorado. The habitat and community types represented by the CFR SIMPPLLE version are presented in Table 30 without further discussion due to the difficulty in determining the ecological status of *P. tremuloides*. The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 30: *Populus tremuloides* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
	Arctostaphylos uva-ursi	*Carex foenea*
	Juniperus communis	*Carex foenea, Poa pratensis*
Populus tremuloides	*Physocarpus monogynus*	*Carex geyeri*
	Shepherdia canadensis	*Carex foenea*
		Festuca thurberi

Source: Alexander 1987.

Pinus flexilis Series

The *Pinus flexilis* series is of minor importance in southern Colorado. Only the *P. flexilis/Arctostaphylos uva-ursi* type was documented (table 31). In this type, *P. flexilis* dominates or co-dominates with *Pseudotsuga menziesii*. *Picea engelmannii* is often sub-dominant in this type. *A. uva-ursi* dominates the understory (25% mean plot cover). *Juniperus communis* is a common associate where herbaceous cover is seldom over trace amounts. This type is found primarily around 9,850 feet on steep south-facing slopes. In addition, *P. flexilis/A. uva-ursi* type provides valuable big game winter range, however,

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[2] Based on *Aspen community types of the Pike San Isabel National Forests* (Report) by David C. Powell and personal communication with Powell, Silviculturist, Pike-San Isabel National Forests. Pueblo, CO.

timber production is low. The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 31: *Pinus flexilis* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Pinus flexilis	*Arctostaphylos uva-ursi*	*Carex rossii*

Source: DeVelice and others 1986.

Pinus contorta Series

As with the *Populus tremuloides* series, DeVelice and others (1986) did not investigate *Pinus contorta* stands due to the considerable disagreement among ecologists regarding the successional status of this species. Many ecologists now believe *P. contorta* may be both a seral and climax species depending on environmental conditions (Mueggler 1985a, as cited in Hess and Alexander, 1986). Furthermore, Peet (1978) states that *Pinus contorta,* along with *P. tremuloides,* plays the primary role in forests of the southern Rocky Mountains. *P. tremuloides* is the dominant seral species in the southern mid-elevation forests with *P. contorta* increasing in importance as one reaches 39° north latitude. Despite the uncertainty as to the successional role of *P. contorta*, Alexander (1987) documents several habitat and community types found on the PSINF of Colorado. The habitat and community types represented by the CFR SIMPPLLE version are presented (table 32) without further discussion due to the difficulty in determining the ecological statue of *P. contorta*. The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 32: *Pinus contorta* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
	Arctostaphylos uva-ursi	*Carex rossii*
Pinus contorta	*Juniperus communis*	*Carex rossii*
	Vaccinium myrtillus	*Carex geyeri*

Source: Alexander 1987.

Picea engelmannii Series

The *Picea engelmannii* series documented by DeVelice and others (1986) has one habitat type (table 33) and is widespread in southern Colorado above 10,500 feet. The *P. engelmannii/Vaccinium myrtillus* habitat type is characterized by the overstory dominance of *P. engelmannii and*, occasionally, at lower elevations immature *Abies lasiocarpa* is present. Furthermore, *Pinus aristata* is found at upper timberline as a seral species. *Vaccinium myrtillus* dominates the understory with cover values from 5 to 95%. The elevational range of this type is from 9,800 to 11,500 feet. Again, due to the limited distribution of this habitat type, it is assumed all *P. engelmannii* stands are eventually colonized by the co-climax species *A. lasiocarpa*. The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 33: *Picea engelmannii* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Picea engelmannii	*Vaccinium myrtillus*	*Carex rossii*

Source: DeVelice and others 1986.

Abies lasiocarpa Series

The *Abies lasiocarpa* series is described as having seven habitat types and two phases (DeVelice and others, 1986). The *A. lasiocarpa* series is found at high elevations, 8,850 to 11,800 feet, throughout the southern Rocky Mountains. *A. lasiocarpa* co-dominates with *Picea engelmannii*. Following stand disturbance at low elevations *Populus tremuloides* is the dominant seral species; however at higher elevations, succession leads directly to *A. lasiocarpa* and *P. engelmannii*. SIMPPLLE for the CFR represents one *A. lasiocarpa* habitat type for southern Colorado due to forb dominated

understories of the other types (table 34). The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 34: *Abies lasiocarpa* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Abies lasiocarpa	*Vaccinium myrtillus*	*Carex rossii*

Source: DeVelice and others 1986.

The *A. lasiocarpa/Vaccinium myrtillus* habitat type is one of the most widespread habitat types throughout the southern Rocky Mountains. *P. engelmannii* and *A. lasiocarpa* co-dominate this type. *Pseudotsuga menziesii* and *P. tremuloides* are the seral species in some stands, whereas *Pinus contorta* was not found in any of the sampled stands. *Vaccinium* species dominate the understory (50% mean plot cover), other shrubs including *Acer glabrum* occur on mesic sites within the type. Elevations for this habitat type range from 8,900 to 11,200 feet on moderate to steep slopes.

Picea aristata Series

The *Picea aristata* series is a dry series occurring at or near timberline in southern Colorado. The series is divided into two habitat types (table 35). Forests in this series often have an open park-like appearance with widely spaced or clumped tree within a *Festuca* meadow. The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 35: *Pinus aristata* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Picea aristata		*Festuca thurberi* *Festuca arizonica*

Source: DeVelice and others 1986.

The *P. aristata/Festuca thurberi* habitat type is a minor type found at elevations exceeding 10,500 feet. The overstory is co-dominated by *P. aristata* and *Picea engelmannii*. The understory is dominated by *F. thurberi* (22% mean plot cover).

The *P. aristata/Festuca arizonica* habitat type is found primarily southern extent of the Sangre de Cristo Mountains at elevations ranging from 8,600 to 10,000 feet on southern to westerly slopes. *Pseudotsuga menziesii* and *P. aristata* often co-dominate the overstory; while the understory cover is predominately *F. arizonica* (14% mean plot cover).

Picea pungens Series

The *Picea pungens* series documented by DeVelice and others (1986) consists of five habitat types. Typically this series is restricted to cold-moist environments throughout the mixed conifer zone. Overstories in this series are highly mixed with species including *Picea engelmannii, Abies lasiocarpa, Pseudotsuga menziesii, Abies concolor, Pinus flexilis, Pinus ponderosa,* and *Populus tremuloides* in seral stands. Stands in this series are found between 7,900 and 9,200 feet on lower slopes protected from extreme sun and wind. SIMPPLLE for the CFR represents three habitat types and one disturbance type in this series (table 36). The reader is referred to the northern habitat type description of this series for the associated climax pathways.

Table 36: *Picea pungens* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Picea pungens	*Arctostaphylos uva-ursi*	*Carex rossii, Muhlenbergia montana*
		Carex foenea
		Festuca arizonica
		Poa pratensis

Source: DeVelice and others 1986.

The *P. pungens/Arctostaphylos uva-ursi* habitat type is a minor that occurs from 7,900 to 9,200 feet on steep, south-facing slopes and ridges. *P. menziesii, P. ponderosa,* and *P. pungens* may co-dominate the overstory. *A. uva-ursi* is the characteristic understory species (24% mean plot cover). In addition, *Juniperus communis*, *Festuca arizonica, Muhlenbergia montana,* and *Carex rossii* are important herbaceous species.

The *P. pungens/Carex foenea* habitat type occurs on north-facing slope from 8,500 to 9,000 feet. The overstory is co-dominated by *P. pungens* and *P. menziesii* with *P. ponderosa* as an important seral species in some stands. The understory is dominated by *C. foenea* having 48% mean plot cover.

The *P. pungens/F. arizonica* habitat type is found on southwesterly, moderate to steep slopes at elevations ranging from 8,200 to 9,200 feet. This habitat is also co-dominated by *P. pungens, P. menziesii,* and P. *ponderosa.* Rich graminoid cover typifies the understory of this type with *F. arizonica* (averaging 11% cover), *Danthonia parryi, Muhlenbergia montana,* and *Poa fendleriana* are all present.

Disturbance by heavy grazing and fire are common throughout this series. *P. tremuloides* is an important seral species following fire. With heavy grazing conversion *Poa pratensis* may occur. This state is accounted for in the CFR SIMPPLLE version.

Non-Forest Habitat Types and Associations

The following section summarizes shrub/graminoid associations found throughout the CFR. While extensive habitat typing has been completed for forested ecosystems, grassland and shrub ecosystem interactions are often not as easily characterized. The majority of the information regarding vegetation associations in this section follows

Shrub-Steppe Habitat Types of Middle Park, Colorado (Tiedeman and others 1987), and *Plant Associations of Region Two* (Johnston 1987). Complete lists of the grassland, shrub, and woodland associations represented by SIMPPLLE pathways are presented in Appendix D.

Pinus edulis-Juniperus Species Type

The *Pinus edulis-Juniperus* species association was not identified as a forest habitat type in any of the literature reviewed for this project, however, Johnston (1987) documented several *P. edulis-J.* species woodland associations for Region Two. SIMPPLLE for the CFR represents three different species associations that may be found in the study area (table 37). See discussion of the *P. edulis-J.* species pathway in the Results section for further details.

Table 37: *Pinus edulis* Shrub Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Pinus edulis-Juniperus scopulorum/monosperma	*Quercus gambelii* *Cercocarpus montanus*	*Carex geyeri, Poa pratensis* *Achnatherum hymenoides* *Bouteloua gracilis*

Sources: Johnston, 1987.

Cercocarpus montanus Type

Johnston (1987) documented nine *C. montanus* shrub associations in Region Two. SIMPPLLE represents two of these associations along the CFR (table 38). See discussion of the *C. montanus* pathways in the Results section for further details.

Table 38: *Cercocarpus montanus* Shrub Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Cercocarpus montanus		*Hesperostipa comata, Bouteloua gracilis* *Muhlenbergia montana*

Sources: Johnston 1987.

Quercus gambelii Type

Quercus gambelii was identified in seven shrub associations throughout Region Two (Johnston 1987). SIMPPLLE represents three *Q. gambelii* associations along the CFR (table 39). See discussion of the *Q. gambelii* pathways in the Results section for further details.

Table 39: *Quercus gambelii* Shrub Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Quercus gambelii	Mesic Shrubs	*Carex geyeri, Poa pratensis, Pascopyrum smithii*
	Amelanchier alnifolia	*Carex geyeri, Poa pratensis, Pascopyrum smithii*
		Bouteloua gracilis

Sources: Johnston 1987.

Artemisia tridentata ssp. wyomingensis/Pascopyrum smithii Habitat Type

The *Artemisia tridentata ssp. wyomingensis-Pascopyrum smithii* habitat type (table 40) occurs at approximately 7,200 to 7,500 feet on slopes not greater than 20% irregardless of aspect. These sites are characterized by undulating terraces and plateau tops having 50% bare ground. Important species in this type include *Chrysothamnus viscidiflorus* and *Bouteloua gracilis* (Tiedeman and others 1987).

Table 40: *Artemisia tridentata ssp. wyomingensis-Pascopyrum smithii* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Artemisia tridentata ssp. wyomingensis-Pascopyrum smithii	*Chrysothamnus viscidiflorus*	*Pascopyrum smithii, Bouteloua gracilis*

Source: Tiedeman and others 1987.

Artemisia tridentata ssp. wyomingensis/Pseudoroegneria spicata Habitat Type

The *Artemisia tridentata ssp. wyomingensis/Pseudoroegneria spicata* habitat type (table 41) is found at elevations ranging from approximately 7,500 to 8,200 feet on primarily south and west-facing 0-65% slopes. This type is found on sloping uplands,

ridges, and gravelly outwash terraces. Other important species in this type include *Chrysothamnus viscidiflorus* and *Poa fendleriana* (Tiedeman and others 1987).

Table 41: *Artemisia tridentata ssp. wyomingensis/Pseudoroegneria spicata* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Artemisia tridentata ssp. wyomingensis/ Pseudoroegneria spicata	*Chrysothamnus viscidiflorus*	*Pseudoroegneria spicata, Poa fendleriana*

Source: Tiedeman and others 1987.

Artemisia tridentata ssp. wyomingensis/Hesperostipa comata Habitat Type

The *Artemisia tridentata ssp. wyomingensis/Hesperostipa comata* habitat type (table 42) is found from approximately 7,500 to 8,000 feet on all aspects with slopes from 0 to 20%. This habitat type is similar to the *Artemisia tridentata ssp. wyomingensis/Pascopyrum smithii* type in that *Pascopyrum* smithii is an important species, and bare ground averages 30%. However, this type occurs at lower elevations, on different soil types, and the understory is dominated by *Hesperostipa comata* (Tiedeman and others 1987).

Table 42: *Artemisia tridentata ssp. wyomingensis/Hesperostipa comata* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Artemisia tridentata ssp. wyomingensis/ Hesperostipa comata	*Chrysothamnus viscidiflorus*	*Hesperostipa comata, Pascopyrum smithii*

Source: Tiedeman and others 1987.

Artemisia tridentata ssp. vaseyana/Festuca thurberi Habitat Type

The *Artemisia tridentata ssp. vaseyana/Festuca thurberi* habitat type (table 43) is found at elevations ranging from approximately 8,300 to 9,500 feet on most aspects, but is confined to north and east aspects at lower elevations. The overstory is dominated by *A. tridentata ssp. vaseyana* with the understory dominated by large tufts of *Festuca*

thurberi. On disturbed sites *Chrysothamnus* species may dominate the site (Tiedeman and others 1987).

Table 43: *Artemisia tridentata ssp. vaseyana/Festuca thurberi* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Artemisia tridentata ssp. vaseyana/ Festuca thurberi		*Festuca thurberi, Hesperostipa comata,* upland Carex species

Source: Tiedeman and others 1987.

Artemisia tridentata ssp. vaseyana/Festuca idahoensis Habitat Type

The *Artemisia tridentata ssp. vaseyana/Festuca idahoensis* habitat type (table 44) is found from approximately 7,700 to 8,900 feet on slopes from 0 to 20%. At higher elevations this type is found south and west/facing aspects and at lower elevations mostly east aspects. This type occupies swale and shallow snowdrift areas at lower elevations and plateaus of deep soils at higher elevations. A dense cover of *A. tridentata ssp. vaseyana* dominates the overstory. A moisture-indicating species association known as the Festuca idahoensis union characterizes the understory. This union is a group of species that commonly occur together, but none of which distinctively dominates the layer. Important species in this union include *Festuca idahoensis, Carex* species, and *Lupinus* species among others. Important species of this type, which are not associated with the Festuca union, include *Chrysothamnus viscidiflorus,* and *Poa fendleriana*. Heavy grazing may shift graminoid dominance to *Poa fendleriana* (Tiedeman and others 1987).

Table 44: *Artemisia tridentata ssp. vaseyana/Festuca idahoensis* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Artemisia tridentata ssp. vaseyana/ Festuca idahoensis	Mesic Shrubs	*Festuca idahoensis, Poa fendleriana*

Source: Tiedeman and others 1987.

Purshia tridentata/Artemisia tridentata ssp. vaseyana Habitat Type

The *Purshia tridentata/Artemisia tridentata ssp. vaseyana* habitat type (table 45) is found at elevations ranging from approximately 7,800 to 9,000 feet on rolling uplands and mountain slopes. The overstory is characterized by the co-dominance of *Purshia tridentata* and *A. tridentata ssp. vaseyana.* Bare ground averages 15% and the understory is by *Pseudoroegneria spicata* or *Poa fendleriana* and *Carex* species. *Festuca idahoensis* is an important climax species in this habitat type; however, it is not always represented at each site (Tiedeman and others 1987).

Table 45: *Purshia tridentata/Artemisia tridentata ssp. vaseyana* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Purshia tridentata/ Artemisia tridentata ssp. vaseyana	*Amelanchier alnifolia*	*Festuca idahoensis,* upland Carex species

Source: Tiedeman and others 1987.

Amelanchier alnifolia/Pseudoroegneria spicata Habitat Type

The *Amelanchier alnifolia/Pseudoroegneria spicata* habitat type (table 46) is found at 7,800 to 8,500 feet on primarily south and west facing slopes with 30 to 70% gradient. This type found along steep, cobbly and gravelly mountain slopes, and has an average of 50% bare ground. The overstory is dominated by *Amelanchier alnifolia* while the understory is primarily *Pseudoroegneria spicata*. *Ericameria parryi* and *Achnatherum hymenoides* are important species. *Populus tremuloides* occupies similar sites where changes in relief or increased elevation allow for greater snow accumulation (Tiedeman and others 1987).

Table 46: *Amelanchier alnifolia/Pseudoroegneria spicata* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Amelanchier alnifolia/ Pseudoroegneria spicata		*Pseudoroegneria spicata, Achnatherum hymenoides*

Source: Tiedeman and others 1987.

Amelanchier alnifolia/upland Carex Habitat Type

The *Amelanchier alnifolia/*upland *Carex* habitat type (table 47) is found from approximately 7,300 to 8,500 feet on 25 to 70% slopes with north and east-facing exposure. This type, dominated by *A. alnifolia* with frequent occurrence of *Chrysothamnus viscidiflorus,* has an understory of *Carex* species and those of the *Festuca idahoensis* union. There is little bare ground naturally occurs in this type. *Populus tremuloides* habitat types are slightly moister and cooler than this habitat type (Tiedeman and others 1987).

Table 47: *Amelanchier alnifolia/*upland *Carex* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Amelanchier alnifolia/ upland Carex species	*Chrysothamnus viscidiflorus*	upland Carex species

Source: Tiedeman and others 1987.

Ericameria parryi/Achnatherum hymenoides Habitat Type

The *Ericameria parryi/Achnatherum hymenoides* habitat type is a disturbance type found at elevations ranging from approximately 7,200 to 8,700 feet on 30 to 70% slopes (table 48). This type occurs on primarily south and west-facing slopes and averages more than 70% bare ground. *Ericameria parryi* dominates the overstory with *Achnatherum hymenoides* dominating the understory. These sites are severely eroded and unstable (Tiedeman and others 1987).

Table 48: *Ericameria parryi/Achnatherum hymenoides* Habitat Type Representation in the CFR SIMPPLLE Version.

Overstory	Shrubs	Grasses
Ericameria parryi/ Achnatherum hymenoides	*Artemisia tridentata*	*Achnatherum hymenoides*

Source: Tiedeman and others 1987.

Colorado Front Range Processes

Many of the processes, which influence vegetation, act in a stochastic and species-specific way. For example, when fire burns into a low cover sagebrush stand, the fire will likely burn patches of acuminated litter, dry grasses, and occasional sagebrush plants; the fire may not burn evenly and completely through the stand though. This poses problems when modeling. The system logic has to account for the patchy nature of the burn, and individual species response to the disturbance. Some grasses in the above example will sprout back as growing conditions allow for plant growth. However, species like sagebrush will rely on existing individuals to re-seed the site. Due to the complexity and interaction of many species to disturbance and other natural processes, several standardized species responses to these processes were developed. This logic provides a basis from which the system can be tailored depending on the species and the expectations of the modeling team.

Fire

The fire severity logic for pathway construction is based on the fire regime classification in "Wildland Fire in Ecosystems: effects of fire on flora" (USFS 2000). In this classification fire severity is comprised of the primary fire effects resulting from the intensity of the flame front and the heat released during total fuel consumption. The primary effects are plant mortality and removal of organic materials (USFS 2000). The use of fire severity as the key component for describing fire logic is appealing because fire severity relates directly to the effects of disturbance on the condition and survival of vegetation (USFS 2000). In addition, this classification was intended for broadscale

application and communication of fire's role in ecosystems among resource managers and others. Definitions for the various fire severity classes (USFS 2000) used in the development of the CFR pathways are as follows:

1. *Stand-replacement fire* (applies to forests, woodlands, shrublands, and grasslands)- Fires that kill aboveground parts of the dominant vegetation, changing the aboveground structure substantially. Approximately 80% or more of the aboveground vegetation is either consumed or dies as a result of fires.

2. *Mixed severity fire* (applies to forest and woodlands)- Severity of fire either causes selective mortality in dominant vegetation, depending on different tree species' susceptibility to fire, or varies between understory and stand-replacement.

3. *Light severity fire* (applies to forests and woodlands)- Fires are generally nonlethal to the dominant vegetation and does not substantially change the structure of the dominant vegetation. Approximately 80% or more of the aboveground dominant vegetation survives fires. This class is referred to as the "understory fire regime."

Other fire regime classifications (i.e., Morgan and others 1998) have classified fires in grasslands and some shrubland types as "nonlethal" because non-forest plants recover quickly following fire.

The CFR version of SIMPPLLE defaults all non-forest pathways to stand-replacing fire (except *Pinus edulis-Juniperus* species pathways). This logic is based on the notion that 1) non-forest stand structure is immediately and drastically altered by fire, and 2) to carry fire in non-forest types, fuel loads are often high enough to remove the above-ground portion of the plants. It is important to understand that following stand-replacing fire the regeneration table then selects the most appropriate form of site regeneration. The majority of shrub and grass species will resprout on the site, leading to rapid recovery of the area; whereas, species such as *Artemisia tridentata* will not resprout and

require several decades to recolonize a site. Table 49 illustrates the fire response used for the CFR pathways.

Table 49: Fire Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Stand-Replacing Fire (SRF)	All species revert to grass or shrub pathways. The regeneration table then assigns successional direction.
Mixed Severity Fire (MSF)	**Fire Resistance[1] High**- Reduce species 1 density and multistory stands revert to single story. **Fire Resistance Moderate**- Reduce species 2 densities and multistory stands revert to single story. **Species Combinations of High/Moderate and Low Resistance**- remove the low resistance species and reduce the density by 2. Multistory stands revert to single story. **Fire Resistance Low**- Reduce 2 densities and multistory stands revert to single story. ***Maintain the time-step for the above combinations***
Light Severity Fire (LSF)	**Fire Resistance High/Moderate**- Follows succession. **Fire Resistance Low**- Reduce species 1 density and multi-story stands revert to single story for Large, Large multi-story, Very-Large, and Very-large multi-story. Small and medium stands revert to grass or shrub pathways. ***Maintain species age for the above combinations***

[1] Refers to the relative susceptibility of individual species to fire kill.

Western Spruce Budworm

Western spruce budworm (WSBW), *Choristoneura occidentalis* (Freeman), is the most widely distributed and destructive defoliator of coniferous forests in western North America. Tree hosts include Pseudotsuga *menziesii*, *Abies grandis*, *Abies concolor*, *Abies lasiocarpa*, *Picea pungens*, *Picea engelmannii*, *Picea glauca*, and *Larix occidentalis* (Fellin and Dewey 1982). Western spruce budworm appears as both light and severe infestations in the CFR SIMPPLLE pathways for the following species and associated species combinations: *Abies lasiocarpa*, *Picea engelmannii*, *Abies concolor*, *Pseudotsuga menziesii,* and *Picea pungens*. The western spruce budworm response is shown for the CFR in table 50.

Table 50: Western Spruce Budworm Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Western spruce budworm (WSBW)[1]	**Light WSBW**- Follow succession. **Severe WSBW**- Reduce density by 2 and multi-story stands revert to single story. ***Maintain species age for the above combinations***

[1] Process removes low density *Picea engelmannii.*

Mountain Pine Beetle

Mountain pine beetle, *Dendroctonus ponderosae* (Hopkins), is a member of the bark beetle group. The beetles often attack lodgepole pine stands that are composed of large, well distributed trees, or dense, pole size ponderosa pine stands. Mountain pine beetles are hosted mainly by *Pinus contorta*, *Pinus ponderosa*, *Pinus lambertiana,* and *Pinus glauca* (Amman and others 1989). Mountain pine beetle outbreaks typically occur at intervals of 15 to 20 years in older lodgepole forests and last for six to ten years (Cole and Amman 1980). The CFR SIMPPLLE system captures mountain pine beetle infestations for *P. contorta* and *P. ponderosa* (table 51).

Table 51: Mountain Pine Beetle Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Ponderosa pine mountain pine beetle (PP-MPB)	Reduce density by 2 and multi-story stands revert to single story stands. ***Maintain species age for the above combinations***
Lodgepole pine mountain pine beetle (LP-MPB)[1]	**Light LP-MPB**- Reduce density by 1 and multi-story stands revert to single story. **Severe LP-MPB**- Reduce density by 2 and multi-story stands revert to single story. ***Maintain species age for the above combinations***

[1] Process removes low density *Pinus contorta.*

Spruce Beetle

Spruce beetle, *Dendroctonus rufipennis* (Kirby), is responsible for significant mature *Picea* mortality. Spruce beetle outbreaks cause extensive tree mortality and

modify stand structure by reducing the average tree diameter, height, and density. Remaining trees are often slow growing and small and/or intermediate in-size. Most spruce beetle outbreaks typically originate in windthrown trees. As populations increase, beetles may then enter susceptible, large-diameter standing trees. Trees of greater then 18-inch diameter are attacked first, with beetles moving to smaller diameters as the infestation persists (Holsten and others 1990). The CFR SIMPPLLE version deals with both light and severe spruce beetle infestation for *Picea engelmannii* associated stands (table 52).

Table 52: Spruce Beetle Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Spruce beetle[1] (SPRUCE-BEETLE)	**Light-** Follow succession. **Severe-** Reduce density by 1 and multi-story stands revert to single story. ***Maintain species age for the above combinations***

[1] Process removes low density *Picea engelmannii.*

Douglas-fir Beetle

Douglas-fir beetle, *Dendroctonus pseudotsugae* (Hopkins), attacks *Pseudotsuga menziesii* and occasionally *Larix occidentalis* throughout the western United States, British Columbia and Mexico. Douglas-fir beetle normally kills small groups of trees; however, during beetle outbreaks losses can be dramatic. Losses are greatest in dense stands of *P. menziesii* (Schmitz and Gibson 1996). The CFR SIMPPLLE system logic for Douglas-fir beetle is presented in table 53.

Table 53: Douglas-fir Beetle Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Douglas-fir beetle[1] (DF-BEETLE)	**Only in Large and Very Large**: Reduce density by 1 and multi-story stands revert to single story. ***Maintain species age for the above combinations***

[1] Process removes low density *Pseudotsuga menziesii.*

Pinyon Engraver Beetle

Pinyon engraver beetle, *Ips confuses* (LeConte), is an important agent of disturbance and tree mortality in pinyon-juniper stands of the west. *Pinus edulis* and *Pinus monophylla* are the primary host for this beetle in Utah. Drought is considered a predisposing agent of beetle outbreak for two reasons, 1) moisture stress reduces the production of sap, thus limiting the ability of the tree to 'pitch' attacking beetles, and 2) moisture stress concentrates soluble sugars and other compounds in tree cells, improving the nutritional quality for beetles (UDFFSL No date). Timber stands with old trees (average root collar diameter of 7 to 11 inches), trees with dwarf mistletoe infection, and dense tree stands are most susceptible to engraver beetles infestation (Wilson and Tkacz, 1992 as cited in UDFFSL No date). Table 54 documents pinyon species response to pinyon bark beetle.

Table 54: Pinyon Bark Beetle Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Pinyon Bark Beetle (PIED-BB)	Reduce density by 1 and multi-story stands revert to single story ***Maintain species age for the above combinations***

Root Disease

Laminated root rot, *Phellinus weirii* (Murr.), occurs throughout the Northwestern United States and southern British Columbia, Canada. Trees of all sizes and ages are attacked. However, root rot is often not conspicuous until stands reach 40 years old. Root rot can infest sites indefinitely, substantially reducing productivity in addition to killing individual trees. Root rot is typically found in *Abies concolor*, *Abies grandis*, *Pseudotsuga menziesii*, and *Tsuga mertensiana* (Nelson and others 1981). Root rot was

captured in various combinations of *A. concolor* and *P. menziesii* in the CFR SIMPPLLE version (table 55).

Table 55: Root Disease Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Root Disease (ROOT-DISEASE)	Reduce density by 1 and maintain stand structure. ***Maintain species age for the above combinations***

Windthrow

Along the Colorado Front Range, Veblen (1986) found consistently lower frequencies of *Picea engelmannii* as treefalls. Ninety-five percent of the trees measured fell in an easterly direction, indicating westerly winds were the cause of the treefall. Lower treefall frequencies for *Picea*, combined with the greater longevity of *P. engelmannii* as compared to *Abies lasiocarpa,* imply a lower adult mortality rate for *P. engelmannii*. Thus, even though *A. lasiocarpa* often has a greater proportion of seedlings and saplings in mature *Picea* forests, it does not imply *P. engelmannii* will be replaced by *A. lasiocarpa* in old-growth stands barring large-scale exogenous disturbance. Furthermore, Veblen (1986) concluded that this empirical evidence supports the coexistence of ecologically similar species by means of different life history strategies. Windthrow in the CFR was captured for the *P. engelmannii* and *A. lasiocarpa* stands (table 56).

Table 56: Windthrow Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Windthrow (WINDTHROW)	Reduce density by 1 and reset the stand to seedling/sapling.

Wildlife Browsing

Wildlife browsing may impact many vegetation types by changing the structure and density of shrub and tree species. Krebil (1972) found that heavy elk use on winter

range in Wyoming and Colorado damaged *Populus tremuloides* stands and could lead to eventual type conversion to grasslands (Jones 1974). Furthermore, investigation of *P. temuloides* stands in Yellowstone National Park showed that high elk populations in the 1990s were reducing stand regeneration. In addition, stands in the Estes Valley of Rocky Mountain National Park (RMNP) had only 20% cohort regeneration; yet, regeneration was common across the landscape in RMNP (Suzuki and others 1999). Therefore, the following logic was established to reflect moderate wildlife use. Extreme use as documented by Suzuki and others (1999) was not captured for the CFR version. Shrub species selected for wildlife browsing in the CFR SIMPPLLE version are presented in Appendix E. Table 57 documents species response to wildlife browsing.

Table 57: Wildlife Browsing Response for the Colorado Front Range SIMPPLLE Version.

Process	Response
Wildlife Browsing[1] (WILDLIFE-BROWSING)	Reduce density by 1 (Select shrubs and *Populus tremuloides*). Small and medium size class shrubs.

[1] See Appendix E for species list.

Prairie Dogs

Prairie dog (*Cynomys* species) colonies in American grasslands provide large and distinct patch structures. In areas without human control, prairie dog colony patch size ranges from ten to hundreds of hectares. A study in South Dakota found average colony size ranging from 5 to 250 hectares. These colonies are generally located in areas with deep soils, slopes less than 7%, and little chance of flooding (Whicker and Detling 1988).

Prairie dogs often denude only the area immediately surrounding their burrow entrance. However, dramatic changes to the surrounding vegetation occur following two or more years of colonization. Studies suggest tall or mid-height plants are replaced by shortgrass species with greater grazing resistance in as little as 15 years of frequent heavy

grazing. Coppock and others (1983) found that in a prairie dog colony colonized for over 26 years, forbs had increased in both relative and absolute biomass, as well as species number. Under prolonged prairie dog grazing and the right combination of other factors, colony patches may become completely dominated by a limited number of forbs or dwarf shrubs (Coppock and others 1983, Whicker and Detling 1988). Table 58 presents the prairie dog invasion logic for the CFR. See Appendix F for a list of graminoid types susceptible to prairie dog invasion.

Table 58: Prairie Dog Invasion Logic for the Colorado Front Range SIMPPLLE Version.

Function	Rule
Prairie Dog Invasion	Only areas with gentle slopes (< 7%), dominated by suitable graminoids are susceptible to prairie dog invasion. Following prairie dog invasion grass cover should be no greater than cover class 2. In addition, the vegetative state should be PG-FORBS/UNIFORM/2. Following three decades of prairie dog colonization the vegetative state should change to FORBS-PG/UNIFORM/2.

Wet and Dry Succession

Within plant associations typical of northwestern grasslands it has been documented that water is a major limiting resource (Krueger-Mangold and others 2004). In the western United States drought is a natural disturbance process. In addition, the timing of seasonal precipitation can greatly influence grassland plant growth. Therefore, both above and below normal precipitation was simulated. This process can be applied to yearly and decadal time-steps. It should be noted that when using this process on yearly time-steps the effect will be exaggerated due the large density cover classes. Figure 1 documents the logic for dry succession. System logic for wet succession is presented in figure 2.

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Figure 1: Graminoid Dry Succession Pathway.

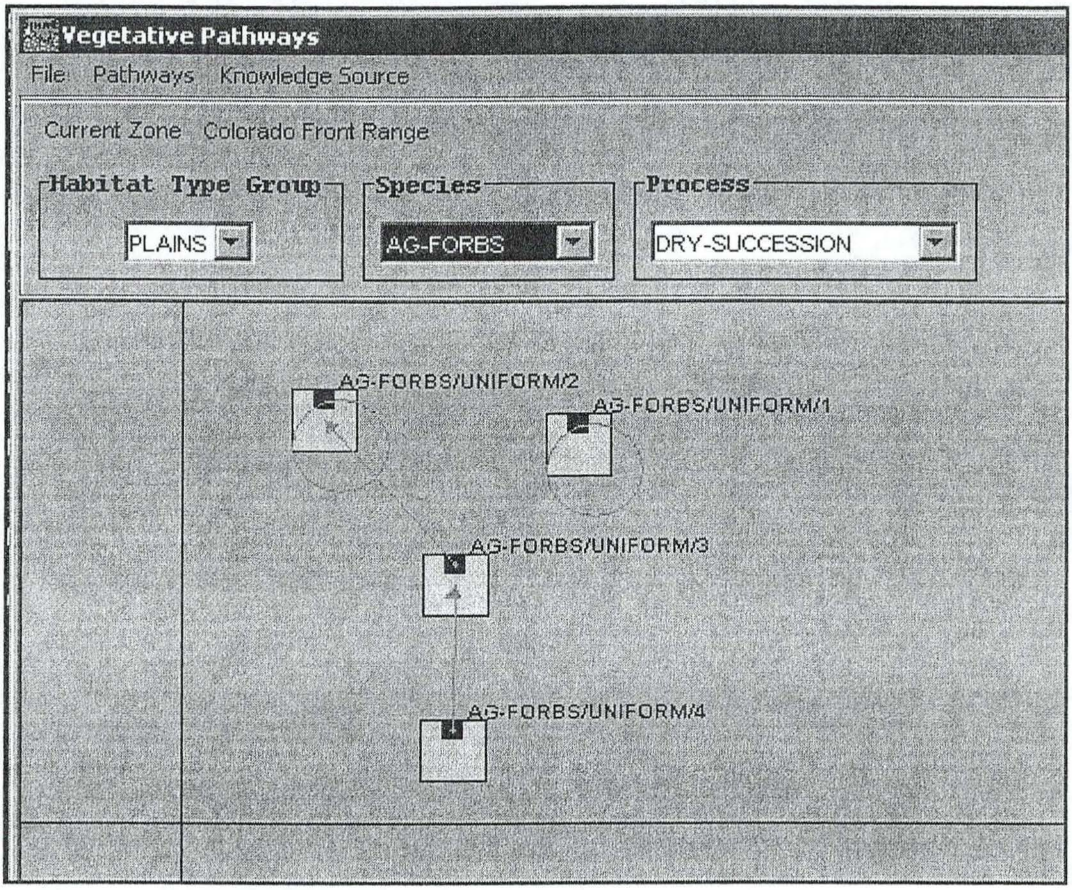
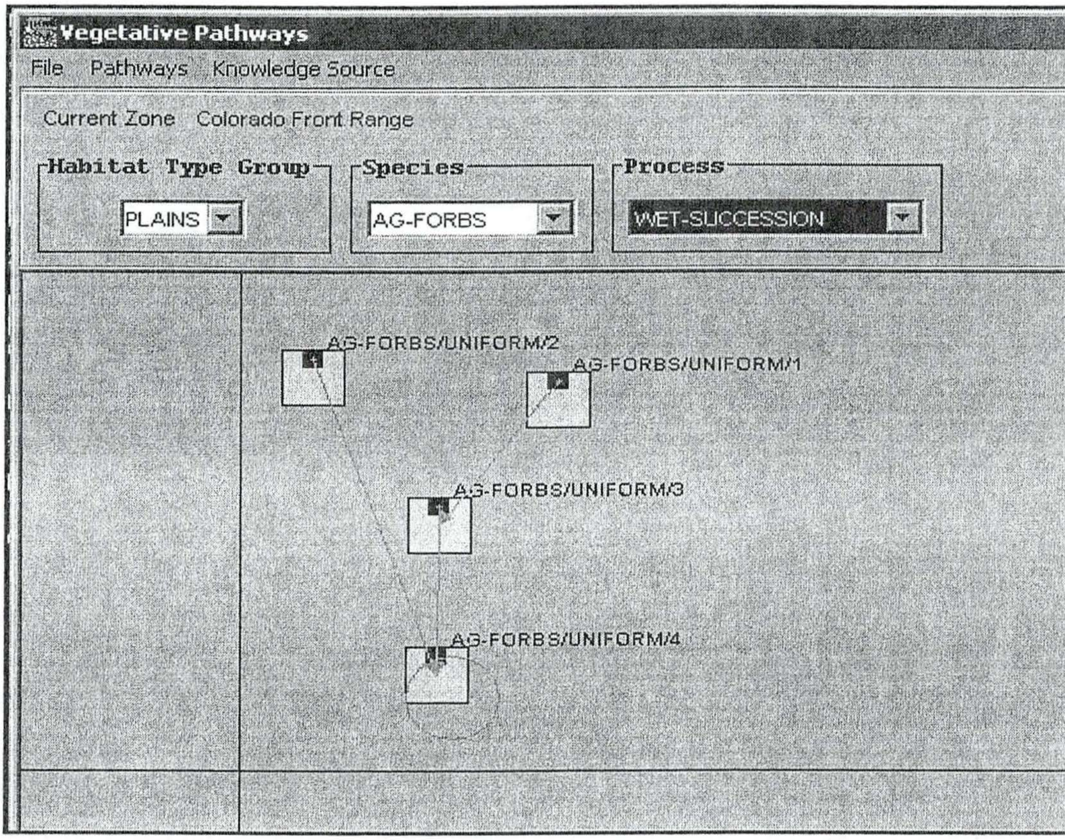


Figure 2: Graminoid Wet Succession Pathway.



Results and Discussion

Following the review and synthesis of the information presented previously, 192 species combinations were identified for system representation. Of these species combinations, 33 represent graminoids (Appendix G), 57 represent shrub combinations (Appendix H), 7 respresent woodland species (Appendix I), and 95 represent trees (Appendix J). These species combinations were further grouped into sub-categories so representative pathways could be built. This resulted in 3 classes of graminoids: low cover, high cover, and alpine/riparian. Therefore, 3 unique graminoids successional pathways represent all species combinations along the CRF. Furthermore, shrub and woodland species were grouped based on phenologic characteristics and disturbance response into 20 unique successional shrub and woodland pathways. Forest species combinations were grouped by dominant species, with different successional pathways accounting for species combination and ecological zone.

Combinations of the various lifeforms represent 80 habitat types, community types, and dominant species associations (Appendices B, C, D). Forest, shrub, and woodland pathways are assumed to operate on decade time-steps. Graminoid pathways may be run on yearly time-steps. Furthermore, many of the pathways represent two species combinations[3] (i.e., PICO-PSME). It should be noted that the first species in the combination (i.e., PICO) is assumed to be the dominant species, and as such, exerts its influence over the pathway. Therefore, if the first species is a seral species the pathway

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[3] Derived from the CVU GIS data from Region Two. Three species combinations were reduced to the first two species in the combination.

will eventually give way to the climax species for the particular zone or species combination (i.e., PICO-PSME transitions to PSME-PICO).

The results and discussion section is divided into five sections. We provide a section on ancillary logic, describe and discuss the pathway logic use to develop the non-forest pathways, summarize the forest pathways, and provide the regeneration logic for the non-forest pathways.

Ancillary System Logic

The following section presents ancillary system logic, which were identified from the literature review, and developed to enhance the behavior of the CFR version of SIMPPLLE. This logic describes special circumstances or specific species responses, which could not be incorporated into the various compartments of SIMPPLLE.

Shading

Following large disturbance processes such as fire or timber harvest overstory forest cover is greatly reduced. Large reduction in forest cover provide an opportunity for grasses and shrubs to dominate for several years following forest disturbances until overstory cover increases and "shades out" these species. Mueggler (1965) found a high negative correlation between shrub cover and tree canopy. Furthermore, he found that in forest types of Idaho shrubs reached their maximum cover in 20 to 30 years post-disturbance. Therefore, the shading rule within SIMPPLLE should be applied to those species with intermediate or no tolerance to shade (Appendix E). Table 59 presents system logic for shading in the CFR version of SIMPPLLE.

Table 59: Shading Logic for the Colorado Front Range SIMPPLLE Version.

Function	Logic
Shading[1]	Maximum shrub density class is 2 following two decades of forest cover equal to cover class 3 or 4. Apply to all species with intolerant or intermediate shade tolerance.

[1] See Appendix E for species list.

Conifer Seedling Establishment and Encroachment

Forest-grassland ecotones in the western United States appear unstable. Tree invasion into grasslands has occurred since the mid-1800s. For example, ponderosa pine has invaded prairie grasslands while juniper has increased its range throughout the west. Along the CFR nineteenth century photographs show grass cover in areas currently dominated by ponderosa pines (Mast and others 1997). White (1985) stated frequent droughts and/or competition for water with bunch grasses may limit ponderosa pine establishment at the lower timberline ecotone. White (1985) proposed four limiting factors when considering successful ponderosa pine regeneration in the pine/grass ecotone:

1. Adequate seed production
2. Areas without an abundance of grass cover
3. Adequate moisture in spring and early summer
4. Early mortality due to disturbance

In addition, Kaufman and others (2000) proposed tree recruitment and fire might be related to the same low-frequency climatic cycles. However, the coincident timing of fires and periods of tree recruitment may be spatially disassociated, such that tree mortality from fire may be occurring in one area while tree recruitment may be occurring elsewhere. Similarly, Mast and others (1997) found that above normal spring and summer precipitation combined with decreases in fire provided the greatest increase in

ponderosa pine into grasslands. Moreover, along the pine/grass ecotone topography influenced pine regeneration with the greatest change in tree cover occurring on north facing slopes. Table 60 presents the logic for conifer encroachment.

Table 60: Conifer Encroachment Logic for the Colorado Front Range SIMPPLLE Version.

Function	Logic
Conifer Encroachment	Only areas with grass cover from 71-100% will be considered as "inhibiting" seedling establishment. This applies to all grass species (Appendix B), and should be considered in combination with climatic conditions within SIMPPLLE.

Species Specific Logic and Response Characteristics

- Maximum graminoid cover class 2 exists following one decade of forest or shrub overstory cover equal to cover class 3. Apply to all graminoid species.

- *Chrysothamnus viscidiflorus* will dominate *Artemisia tridentata* and *Artemisia tridentata* ssp. *wyomingensis* stands for up to 15 years following fire. *C. viscidiflorus* persists in stands 40 to 50 years old (Young and Evans 1974). *Ericameria parryi* follows the same logic as *C. viscidiflorus*.

- *Bromus tectorum* understory alters the fire frequency in *Artemisia* communities. Sites in Wyoming have burned 2 to 3 times in 10 years as a result of understory conversion to *Bromus tectorum*. Repeated burning removes *Artemisia* from the community, converting the site to annual grasslands (Howard 1999).

- *Juniperus scopulorum* may produce seed at 10-20 years old, however main seed production begins from 50-200 years old (Scher 2002).

- *Juniperus* invades *Artemisia tridentata* ssp. *wyomingensis* sites and grassland types. *Juniperus* dominates from 46-70 years post fire, *Artemisia* density decreases as *Juniperus* increases (Barney and Frischknecht 1974).

- Maximum *Artemisia tridentata* ssp. *vaseyana* cover class of 3 is reached 40 years post-disturbance. *Artemisia* cover then decreases 1 density for every increase in *Pinus edulis-Juniperus* cover. If *Juniperus* cover equals 3, then *Artemisia* cover is no greater than cover class 1 (Barney and Frischknecht 1974).

- *Pinus contorta* and *Pseudotsuga menziesii* also invade *Artemisia tridentata ssp. vaseyana* areas.

- *Pinus ponderosa* invades grassland types adjacent to established *P. ponderosa* forest types.

- Mountain and alpine meadows have shrub invasion following 1 decade. (Upland *Salix* and *Dasiphora floribunda*).

- Stand-replacing fire or clearcutting forest stands with *Carex geyeri, Calamagrostis canadensis, Calamagrostis purpurascens, Calamagrostis rubescens,* and *Carex rossii* may result in cover class 4 grassland stands, which inhibit forest regeneration. Specifically, *Abies lasiocarpa* regeneration is inhibited following clearcutting (Hess and Alexander 1986).

- Extended heavy grazing (2 decades) in the *Populus angustifolia* or *Picea pungens* type coverts the herbaceous layer to *Poa pratensis* (Hess and Alexander 1986).

- Generally replacement of seral *Populus tremuloides* stands takes 65 years (Ives 1941, as cited in DeVelice and others 1986).

- In stands with *Arctostaphylos uva-ursi* dominated ground cover, graminoid cover should not exceed cover class 1.

- Stand-replacing fire or clearcutting in the *Pinus ponderosa/Quercus gambelii* type results in *Q. gambelii* cover of 4, thus inhibiting pine regeneration (DeVelice and others 1986).

- Where *Abies concolor* is part of the GIS coverage species mix, the polygon should be placed in the ABCO pathways. *Pseudotsuga menziesii* is less shade-tolerant than *A. concolor* and is not considered the climax species when in combination with *A. concolor* (DeVelice and others 1986).

- Upland *Salix* (SALIXU) reaches cover class 4 on burned sites with adjacent seed sources. After 20 years overstory shading logic should begin reducing canopy cover (Mueggler 1965).

Graminoid Pathways

We identified 13 graminoid pathways from GIS coverages. Of theses, the majority were *Carex* and alpine meadow species. To fully represent graminoid diversity and dominant understory species, we included 20 species combinations from habitat type classifications and other literature (Appendix K). Two pathways, annual grass-forbs (AG-FORBS) and perennial grass-forbs (PG-FORBS) are generalized pathways. Graminoids were categorized as low cover, high cover and alpine/riparian graminoids. These categories represent logical groupings depicting characteristics of the majority of stands for a given species. Standardized pathways for these groups were developed, resulting in 3 unique graminoids pathways. The annual grass-forbs pathway represents logic for low cover grasses, while the perennial grass-forbs pathway represents the logic for high cover grasses. Alpine/Riparian pathway logic is represented by the riparian *Carex* species (CAREX). The 3 graminoid pathways do not vary by ecological zone because insufficient literature was identified to justify zonal variations. Not all species combinations are present in each zone. For example, alpine grasses are not found at lower elevations, thus they are only available in the Subalpine and alpine zones. A complete list of graminoid species combinations is presented in Appendix G.

Low Cover Pathways

Low cover graminoid pathways are those which do not generally progress past cover class 3 following succession (figure 3). It should be noted that low cover grasses will reach cover class 4 with the wet succession process. Fourteen species are characterized as low cover species (table 61). Of these species, a variety of situations

may lead to this cover limitation. For example, the soil type associated with the species may be especially cobbly, and well drained providing a site too dry to support cover class 4, as is commonly the case with *Leucopoa kingii* (Tirmenstein 1987). Another example may be the associated overstory cover, which limits shade intolerant species from achieving high ground cover. Of course, there will be exceptions to any rule. That said, some of the ancillary logic attempts to address dramatic understory responses to disturbance or treatment processes.

Figure 3: Low Cover Pathway Succession Logic.

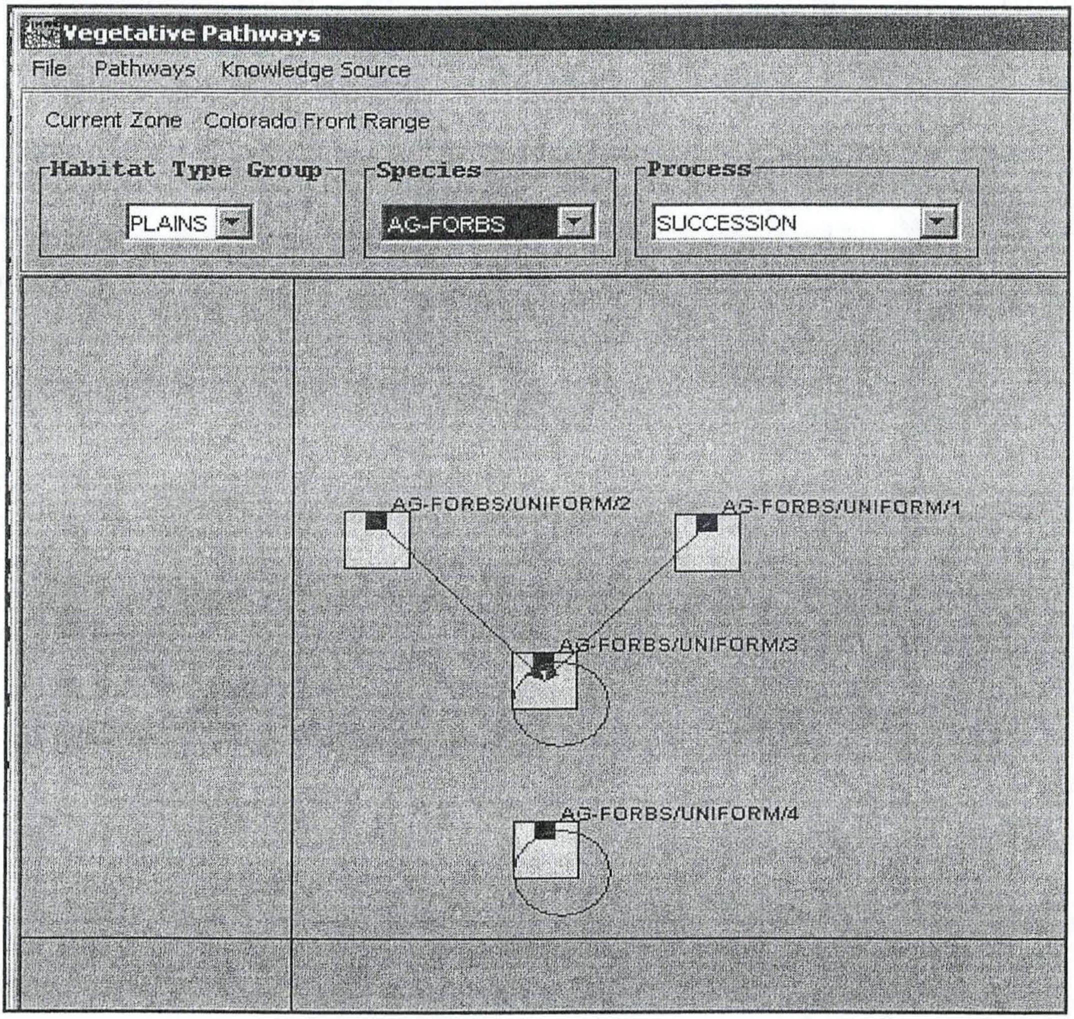


Table 61: Low Cover[1] Pathway Species for the CFR SIMPPLLE Version.

SIMPPLLE Code	Scientific Name
AG-FORBS	Annual grasses-forbs
ACHY	*Achnatherum hymenoides*
BOGR2	*Bouteloua gracilis*
CACA4[2]	*Calamagrostis canadensis*
CAGE2	*Carex geyeri*
CAPU	*Calamagrostis purpurascens*
CAREXU	*upland Carex species*
CAREXU-CARU	*upland Carex-Calamagrostis rubescens*
CARO5	*Carex rossii*
FEAR2-BOGR2[3]	*Festuca arizonica-Bouteloua gracilis*
HECO26	*Hesperostipa comata*
LEKI2	*Leucopoa kingii*
PASM	*Pascopyrum smithii*
POFE	*Poa fendleriana*

[1] Several low cover pathways reach cover class for with the remove of the overstory canopy. The reader is referred to the ancillary logic for further discussion.
[2] CACA4 is assumed to grow only on upland sites in combination with a forest overstory.
[3] FEAR2-BOGR2 was included in the low cover grouping because it is assumed this is the driest phase in the *Pinus ponderosa/Festuca arizonica* habitat type.

High Cover Pathways

High cover pathways were established for those graminoid species, typically achieving a cover class of 4 under normal conditions (figure 4). The high cover species group contains 11 species (table 62). Often these species are found in mesic situations or areas with deep productive soils. *Bromus tectorum,* an annual invasive species, was included in the high cover grouping with the assumption that if it is present in a community it will eventually reach high cover values (>70%), following disturbance (Zouhar 2003). Ancillary rules further define species response to natural and disturbance processes.

Figure 4: High Cover Pathway Succession Logic.

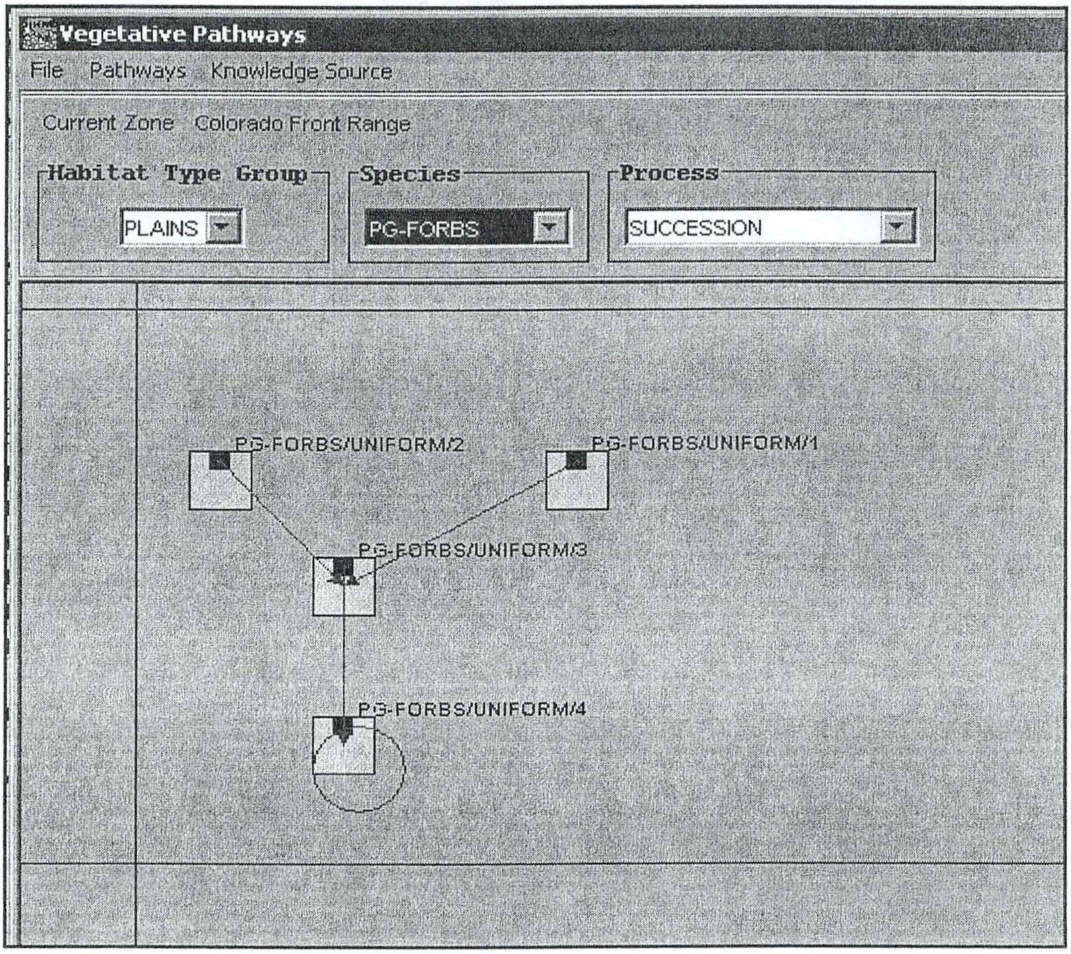


Table 62: High Cover Pathway Species for the CFR SIMPPLLE Version.

SIMPPLLE Code	Scientific Name
PG-FORBS	Perennial grass-forbs
BRTE	*Bromus tectorum*
FEAR2	*Festuca arizonica*
FEAR2-DAPA2	*Festuca arizonica-Danthonia parryi*
FEAR2-MUMO	*Festuca arizonica-Muhlenbergia montana*
FEID	*Festuca idahoensis*
FETH	*Festuca thurberi*
JUBAL-CAGE	*Juncus balticus-Carex geyeri*
MUMO	*Muhlenbergia montana*
POPR	*Poa pratensis*
PSSP6	*Pseudoroegneria spicata*

Alpine/Riparian Pathways

Alpine/riparian pathways are those that exhibit rapid growth to cover class 4 (figure 5). It is assumed that these species dominate the ground cover in their respective areas. For example, riparian *Carex* types are typically wetland indicators and exhibit little species diversity within an area (Cope 1992). Furthermore, alpine grasses often dominate sites along ridgelines or other severe sites not occupied by trees. The CFR version of SIMPPLLE contains 7 alpine/riparian species combinations (table 63).

Figure 5: Alpine/Riparian Pathway Succession Logic.

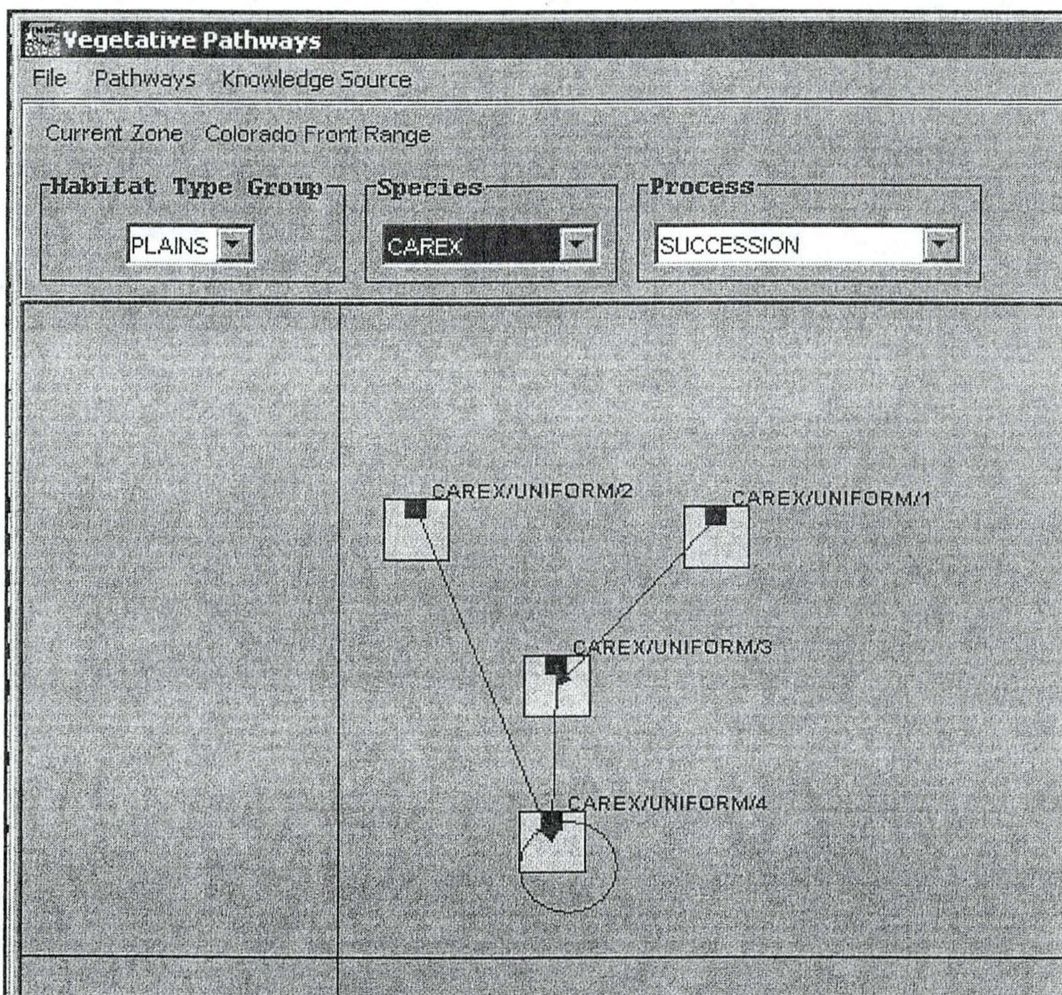


Table 63: Alpine/Riparian Pathway Species for the CFR SIMPPLLE Version.

SIMPPLLE Code	Scientific Name
CAEL3-CARUD	*Carex elynoides-Carex rupestris*
CAFO3	*Carex foenea*
CAREX	*Carex* species
CAREX-JUNCU	*Carex-Juncus* species
CARUD-FEBRC	*Carex rupestris-Festuca brachyphylla*
PHCO9-POAL2	*Phleum alpinum-Poa alpina*
POAL2-CAEL3	*Poa alpina-Carex elynoides*
POAL2-KOMY	*Poa alpina-Kobresia myosuroides*

Shrub and Woodland Pathways

Of the pathways constructed for the CFR SIMPPLLE version, 57 species combinations represent shrub associations (Appendix H) and 7 combinations represent woodland associations (Appendix I). Forty-three of the 57 shrub pathways were identified from the GIS layer. The remaining 14 pathways were identified as ecologically important from the literature (Appendix L). Two additional pathways, mesic shrubs (MESIC-SHRUB) and xeric shrubs (XERIC-SHRUB) are generalized pathways.

Many of the shrub pathways are combinations of a dominant species and a secondary species (i.e., there are 11 *Cercocarpus montanus* pathway combinations). To standardize the modeling process, growth characteristics of the dominant species in the combination was considered as the driver for the species combination. Furthermore, species such as *Acer glabrum* and *Alnus incana*, which exhibit rapid growth, were grouped in the same successional pathway. As a result of these groupings, the CFR version of SIMPPLLE contains 20 unique shrub and woodland pathways (Appendix M). Pathway growth characteristics do not change based on the ecological zone. Changes in growth rate among different individuals of the same species of shrub may differ among soil type or micro-site as well as ecological zone; however, specific literature to document these changes along the CFR was not available. While pathway growth

characteristics do not change by ecological zone, the species combinations represented in an ecological zone due change. For example, *Quercus* and *Cercoparus* species combinations are not included in the alpine zone because conditions in the alpine zone are beyond the ecological amplitude of these species. Pathways were constructed to represent the majority of individuals within a species.

The following section describes the unique non-forest successional pathways. In addition, pertinent species information will be presented to provide some justification of pathway logic.

Acer glabrum Based Pathways

Acer glabrum is a native, deciduous tall shrub or small tree typically developing into a multi-stemmed shrub from 5 to 6.5 feet tall, found from 5,000 to over 12,000 feet in Colorado. Following top-kill, *A. glabrum* sprouts from the root crown (Anderson, 2001a). However, in Montana, Crane and others (1983) found resprouts might not set seed for 3 years following disturbance. *A. glabrum* develops rapidly following disturbance, growth modeling estimates that the species may reach up to 10 feet one decade after disturbance. Maximum *A. glabrum* height is reached within 3 or 4 decades (Anderson 2001a).

Arno and Ottmar (1994) characterized *A. glabrum* as fire dependent, and as such may decline with fire exclusion. Following fire, rapid growth of *A. glabrum* may moderately inhibit conifer seedling establishment and growth. Repeated fire may result in seral shrubfields in the northern Rockies (Anderson 2001a).

Three species combinations are represented by the *A. glabrum* pathway logic (table 64). While both *A. incana* and *B. occidentalis* are associated with riparian areas, they exhibit rapid growth following disturbance and the ability to resprout from the root crown or basal buds following fire (Uchytal 1989a, 1989b). Furthermore, *A. incana* may form dense thickets (Uchytal 1989a). Therefore, these three species groupings are represented by one generalized successional pathway. Due to the rapid growth of both species all states move to the large size class within one decade. Furthermore, because *A. glabrum* has the ability to create shrubfields, density class 4 is represented. However, the GIS coverage provided shows a maximum *A. glabrum* cover of 10%, therefore, the pathway progresses to cover class 3 and cycles (Appendix M). A shading response from the system will reduce the canopy cover further.

Table 64: Species Represented by the *Acer glabrum* Pathway Logic.

SIMPPLLE Code	Species Name
ACGL	*Acer glabrum*
ALINT	*Alnus incana* species *tenuifolia*
ALINT-BETOC2	*Alnus incana* species *tenuifolia-Betula occidentalis*

Amelanchier alnifolia Based Pathway

Amelanchier alnifolia is a native, deciduous shrub or small tree reaching heights from 3 to 26 feet at maturity and is found from 5,000 to 10,000 feet in Colorado. *A. alnifolia* reproduces by seed, sprouting from the root crown, rhizomes, and layering. However, the most common form of reproduction is vegetative sprouting (Howard 1997).

A. alnifolia is a fire-dependent species and declines with fire exclusion (Arno and Ottmar 1994). It may persist in the forest understory for decades but will eventually die off with canopy closure (Howard 1997).

A. alnifolia is the only species represented by this pathway logic (Appendix M). Species growth progresses more slowly than the *Acer glabrum* pathways, and does not increase to cover class 4. Cover class 4 was absent in the GIS coverages and *A. alnifolia* does not dominate sites along the CFR. However, *A. alnifolia* is considered an important species in various shrub types.

Artemisia tridentata Based Pathways

Artemisia tridentata is represented in the ARNF GIS coverages, however the subspecies *tridentata, wyomingensis,* and *vaseyana* are not denoted. Knowledge of the dominant subspecies is important as subspecies grow on sites with different productivity, fuel build-up, and fire regimes. *A. tridentata* ssp. *tridentata* is documented as reaching heights of nearly 14 feet on sites with deep, fertile soils. In contrast, *A. tridentata* ssp. *wyomingensis* has a maximum height of 2.6 feet and grows on shallow, well drained soils, and hotter sites. *A. tridentata* ssp. *vaseyana* is predominantly found in the warm desert to montane parkland in deep, moist, and cool soils at maximum heights less than 3 feet tall (Wisdom and others 2003). Despite the differences among growth form, and site characteristics, the land cover type classification for the Great Basin Ecoregion and Nevada grouped the *A. tridentata* ssp. *tridentata* and *A. tridentata* ssp. *tridentata* associations into the Wyoming –basin big sagebrush land cover type (Wisdom and others 2003). Furthermore, the sagebrush encountered in the ARNF is presumed to be *A. tridentata* ssp. *wyomingensis*. Therefore, the CFR SIMPPLLE version combined the *A. tridentata* ssp. *tridentata* and *wyomingensis* into one sagebrush pathway. The

successional pathway for *A. tridentata* ssp. *vaseyana* is presented in the following section.

Artemisia tridentata ssp. *wyomingensis* is a native shrub that is the most drought tolerant of the three major big sagebrush subspecies. *A. tridentata* ssp. *wyomingensis* is a long-lived species, Ferguson (1964, as cited in Howard 1999) found the lifespan of some plants exceeded 150 years. However, growth is slower for this subspecies than the other two subspecies. In addition, drought conditions favor the establishment of *A. tridentata* ssp. *wyomingensis* over bunchgrasses (Howard 1999).

Artemisia tridentata ssp. *wyomingensis* is not a sprouting shrub, and is easily killed by fire. *A. tridentata* ssp. *wyomingensis* must establish from the seedbank, remnant plants, or plants in adjacent areas (Howard 1999). Houston (1973, as cited by Young and Evans 1978) found the fire frequency for sage/grass types in Yellowstone to be 32 to 70 years. Others have reported fire frequencies from 10 to 70 years (Howard 1999) and fire is the primary means of renewal for decadent stands.

In areas heavily invaded by *Bromus tectorum* fire regimes have been radically altered. The fire spread and frequency increases with an abundant *Bromus tectorum* understory because this annual is very flammable and forms more continuous cover. *A. tridentata* ssp. *wyomingensis* sites in southern Idaho have burned two to three times in 10 years. The repeated burning removes *A. tridentata* ssp. *wyomingensis* from the site and inhibits sage re-establishment. In some instances sagebrush sites are converted to annual grasslands. Re-establishment of *A. tridentata* ssp. *wyomingensis* following fire is slow (Howard 1999). Wambolt and Payne (1986) failed to find *A. tridentata* ssp. *wyomingensis* seedlings six years after a prescribed fire.

Five species combinations are represented in the *A. tridentata* ssp. *wyomingensis* pathway (table 65). Given *A. tridentata* ssp. wyomingensis' slow growth and establishment, the pathway slowly moves to cover class 3 medium height stand (Appendix M). Twenty years is required to move small size class stands to the medium size class because these sites are typically water limited and in low productivity soils. The *A. tridentata ssp. wyomingensis-C. viscidiflorus* pathway is a post-disturbance pathway. While *C. viscidiflorus* is a common associate in *Artemisia* sites, it may dominate a stand for up to 15 years post-fire, returning to pre-burn levels within 20 to 25 years (Tirmenstein 1999). Therefore, this pathway is a transition pathway from *C. viscidiflorus* dominated site to a site dominated by *Artemisia*.

Table 65: Species Represented by the *Artemisia tridentata* Pathway Logic.

SIMPPLLE Code	Species Name
ARTR2	*Artemisia tridentata*
ARTR2-CEMO2	*Artemisia tridentata-Cercocarpus montanus*
ARTR2-JUCO6	*Artemisia tridentata-Juniperus communis*
ARTRW8	*Artemisia tridentata ssp. wyomingensis*
ARTRW8-CHVI8	*Artemisia tridentata ssp. wyomingensis-Chrysothamnus viscidiflorus*

Artemisia tridentata ssp. vaseyana Based Pathways

Artemisia tridentata ssp. *vaseyana* is a native evergreen shrub found at the upper elevational range of sagebrush in montane valleys and on foothill slopes and high ridges. In Colorado, *Artemisia tridentata* ssp. *vaseyana* occurs at elevations from 7,760 to 8,480 feet. This species grows in full sun but will tolerate some shade when growing in association with mature conifers (Johnson 2000).

Artemisia tridentata ssp. *vaseyana* does not sprout after fire and is easily killed by even by light severity fires. Presettlement fire return intervals for *Artemisia tridentata* ssp. *vaseyana* ranges from 15 to 25 years (Johnson 2000). In southwest Montana, Arno

and Gruell (1983) consider average fire return interval of 20 years sufficient to control *Artemisia tridentata* ssp. *vaseyana* invasion into grasslands. *Juniperus* woodlands (Burkhardt and Tisdale 1976), *Pinus contorta* (Johnson 2000), and *Pseudotsuga menziesii* (Arno and Gruell 1983) have invaded *Artemisia tridentata* ssp. *vaseyana* communities as a result of fire suppression. *Artemisia tridentata* ssp. *vaseyana* can act as a nurse plant for *Juniperus occidentalis.* Burkhardt and Tisdale (1976) concluded that fire return intervals of 30 to 40 years would control juniper invasion into *Artemisia tridentata* ssp. *vaseyana* communities. Following lethal fires *Artemisia tridentata* ssp. *vaseyana* may return to preburn densities in 15-20 years, however, stands may progress more slowly with intense fires. In one study the first nine years of post fire growth was slow, but the following 18 years sage cover increased greatly (Johnson 2000).

Two species combinations are represented by the *A. tridentata* ssp. *vaseyana* pathway logic (table 66). Due to the mesic and more productive nature of the *A. tridentata* ssp. *vaseyana* sites, progression from the small size class to medium takes only one decade as compared to two with ssp. *wyomingensis.* The transition time from cover class 2 to cover class 3 is also reduced, taking one decade as opposed to two decades (Appendix M). All stands will culminate at cover class 3. The *A. tridentata* ssp. *vaseyana-P. tridentata* pathway is a transition pathway to the climax *P. tridentata* dominated or co-dominated stand. *P. tridentata* is also sensitive to fire but reestablishes to pre-burn levels in about 30 years following fire (Zlatnik 1999).

Table 66: Species Represented by the *Artemisia tridentata* ssp. *vaseyana* Pathway Logic.

SIMPPLLE Code	Species Name
ARTRV	*Artemisia tridentata ssp. vaseyana*
ARTRV-PUTR2	*Artemisia tridentata ssp. vaseyana-Purshia tridentata*

Arctostaphylos uva-ursi Based Pathway

Arctostaphylos uva-ursi is a native evergreen, prostrate shrub found between 6,000 and 11,700 feet in Colorado. Regeneration of the shrub is primarily asexual by stolons. *A. uva-ursi* is a seral, shade-intolerant species that grows best in high light situations. Thus, it is often the dominant understory species found in open *Pinus contorta, Pinus flexilis,* and *Pinus ponderosa* forests. It is also found *Pseudotsuga menziesii, Abies lasiocarpa,* and *Populus tremuloides* forests (Crane 1991).

Arctostaphylos uva-ursi is a sprouting shrub adapted to fires of low severity and high frequencies, but can also survive moderate fire. Furthermore, it is resistant to ignition, thus inhibiting fire spread in light flashy fuels (Crane 1991). It has been reported by Rowe (1983, as cited by Crane 1991) that *A. uva-ursi* seeds in the upper soil layers survive fire and may be stimulated by heat to germinate. In Colorado, Clagg (1975, as cited by Crane 1991) found that *A. uva-ursi* dominated the understory for the first century following fire in a *P. contorta* stand.

While numerous species combinations exist for *A. uva-ursi* understories, only the *A. uva-ursi* pathway is modeled in SIMPPLLE. Based on the GIS coverages, *A. uva-ursi* cover did not exceed a mean value of 13%, but a maximum cover of 58% was found in the southern portion of the CFR. Given the low mean cover of *A. uva-ursi*, the pathway reaches cover class 2 and cycles (Appendix M).

Cercocarpus montanus Based Pathways

Cercocarpus montanus is a native, deciduous, xerophytic shrub or small tree reaching heights up to 19.8 feet. *C. montanus* is likely long lived, reaching 54 years old

in the Uintah Basin of Utah. *C. montanus* distribution is dependent on moisture availability and is commonly found in coarse, shallow, well-drained soils. While *C. montanus* is somewhat shade tolerant, growing under *Pinus ponderosa* and *Pseudotsuga menziesii* canopies, it prefers sites without a forest canopy (Marshall 1995a). *C. montanus* fills a variety of successional roles. In Utah, Brotherson and others (1984) found that on high elevation north slopes *C. montanus* appears to be a seral species transitioning into mountain shrub types. While on the more xeric southern exposures the trend was progressing slowly if at all. It is assumed the sites for the CFR SIMPPLLE version are relatively stable, maintaining *C. montanus* dominance.

Cercocarpus montanus burns less readily than many other species, and sprouts vigorously from the root crown following most fires. Currently however, increased fuel loads in these stands produce more severe fires than observed historically in these dry open stands (Marshall 1995a).

Cercocarpus montanus pathway represents thirteen species combinations (table 67). The pathway logic for these species progresses from the small to medium size class in one decade. The average *C. montanus* canopy cover, based on the GIS information for the study area, is between 18 and 24%. Thus, this pathway reaches cover class 2 and cycles. It is also assumed these stands do not reach tree stature and remain in the medium size class (Appendix M).

Table 67: Species Represented by the *Cercocarpus montanus* Pathway Logic.

SIMPPLLE Code	Species Name
XERIC-SHRUB	Generalized xeric shrub species
CEMO2	*Cercocarpus montanus*
CEMO2-ARTR2	*Cercocarpus montanus-Artemisia tridentata*
CEMO2-ARUV	*Cercocarpus montanus-Arctostaphylos uva-ursi*
CEMO2-DAFL3	*Cercocarpus montanus-Dasiphora floribunda*
CEMO2-JUCO6	*Cercocarpus montanus-Juniperus communis*
CEMO2-PHMO4	*Cercocarpus montanus-Physocarpus monogynus*
CEMO2-PUTR2	*Cercocarpus montanus-Purshia tridentata*
CEMO2-QUGA	*Cercocarpus montanus-Quercus gambelii*
CEMO2-RIBES	*Cercocarpus montanus-Ribes* species.
CEMO2-RICE	*Cercocarpus montanus-Ribes cereum*
CEMO2-SALIXU	*Cercocarpus montanus*-upland *Salix* species
CEMO2-SYOR2	*Cercocarpus montanus-Symphoricarpos oreophilus*

Chrysothamnus viscidiflorus Based Pathways

Chrysothamnus viscidiflorus is a native low growing (1-3.6 feet) shrub that reproduces by resprouting and vigorous seed production. It grows on dry, well drained course-textured soils, and is drought adapted and may occur in deserts or semi-desert environments (Tirmenstein 1999a). Several subspecies exist (McArthur and others 1986, as cited by Tirmenstein 1999a), yet for the purpose of the CFR system all subspecies are treated together.

Chrysothamnus viscidiflorus is a subdominant in many *Artemisia* communities and increases dominance as a result of root sprouting in response to disturbance in these communities. Following root sprouting the seed produced renews the dominance of the *C. viscidiflorus* community for at least 15 years, while *C. viscidiflorus* will persist in *Artemisia* dominated communities for 40 to 50 years (Young and Evans 1974).

Two species combinations are represented by the *C. viscidiflorus* pathway logic (table 68). Limited information was available for *Ericameria parryi* and was assumed to have a similar growth and disturbance response. Therefore it is included in the same pathway logic. This pathway is meant to represent a seral disturbance community in

which cover class values increase quickly to class 4 (Appendix M). Ancillary rules add further functionality to the interaction of *C. viscidiflorus* and *Artemisia* communities.

Table 68: Species Represented by the *Artemisia tridentata* Pathway Logic.

SIMPPLLE Code	Species Name
CHVI8	*Chrysothamnus viscidiflorus*
ERPAA4	*Ericameria parryi*

Dasiphora floribunda Based Pathway

Dasiphora floribunda is a native, cold tolerant, deciduous shrub. The plant is relatively long lived with plants found to be up to 36 years old. The primary means of reproduction is seed, however, *D. floribunda* sprouts from the root crown following disturbance. Vegetative reproduction (adventitious rooting of prostrate stems) has been recorded. Growth rates have been reported as slow. *D. floribunda* occupies a wide range of sites from low valleys to mountain peaks, riparian areas to subalpine meadows and upland areas. *D. floribunda* has been characterized as a transitional species from wetland sites to drier upland areas. It has fair to weak drought tolerance, preferring open sites but will grow in moderate shade (Anderson 2001b).

Fire will top kill *D. floribunda* but plants will resprout readily from the surviving root crown. If *D. floribunda* is found growing in dense stands it may increase fire spread and intensity due to its fibrous bark. However, fire occurs infrequently on *D. floribunda* sites often as a result of insufficient fuel or mesic conditions (Anderson 2001b).

Only *D. floribunda* is represented by this pathway. Initial height growth of the species is relatively slow taking two decades to progress to the medium size class (Appendix M). Based on the GIS coverage, *D. floribunda* is generally found in low cover classes at lower elevations in grass dominated types. However, all elevations and

species combination are represented. The *D. floribunda* pathway progresses to cover class 2 and cycles.

Jamesia americana Based Pathway

Jamesia americana is a native shrub growing to 6 feet tall in mesic conditions among cliff and rock habitats (Holmgren and Holmgren 1989). The growth rate for this shade intolerant species is moderate, as it reaches 3 feet after 20 years. *J. americana* sprouts following fire disturbance (USDA 2004). Further information for *J. americana* is limited, however it was documented in the *Pseudotsuga menziesii* habitat type of the ARNF by Hess and Alexander (1986). The type is described as occurring on steep slopes in shallow, rocky, coarse-textured soils. *Pinus ponderosa* and *Juniperus scopulorum* are common associates in this type (Hess and Alexander 1986)

Jamesia americana is the only species represented by this pathway. The pathway proceeds relatively slowly, taking two decades, to achieve a medium size class. This pathway proceeds to cover class 2 and cycles (Appendix M).

Juniperus communis Based Pathway

Juniperus communis is a native evergreen shrub that grows on a variety of sites but typically is found throughout dryer wooded hillsides. *J. communis* is a long lived plant with some individuals reaching 170 years old. Throughout most of its range *J. communis* grows as a low decumbent shrub, however in some areas it grows to 13 feet. This pathway assumes *J. communis* to take the decumbent growth form. Thus, height at maturity will range from 2 to 5 feet.

Juniperus communis does not sprout after fire, some seeds may survive and germinate post-fire, however, other seed is brought to the site by birds, or mammals contributing to the slow post-fire reestablishment. A study in Colorado found *J. communis* took from 8 to 18 years to appear in post-fire communities and it has been found to be an important species even after 100 years post disturbance in high elevation forests (Tirmenstein 1999b).

Three combinations of species are represented by the *J. communis* pathway (table 69). This pathway moves slowly (2 decades) to the medium size class. A large size class is not available. The pathway increases to cover class 2 and cycles (Appendix M).

Table 69: Species Represented by the *Juniperus communis* Pathway Logic.

SIMPPLLE Code	Species Name
JUCO6	*Juniperus communis*
JUCO6-ARUV	*Juniperus communis-Arctostaphylos uva-ursi*
JUCO6-SALIXU	*Juniperus communis*-upland *Salix* species

Mesic Shrub Based Pathway

The mesic shrub pathway is a generalized pathway based on species such as *Prunus virginiana* and *Symphoricarpos* species. The GAP landcover analysis for Colorado classified mesic shrubs as "most often Rocky Mountain maple (*Acer glabrum)*, serviceberry (*Amelanchier alnifolia*), and/or chokecherry (*Prunis virginiana*) are dominant or co-dominant" (CDW 1998). Due to the previous representation of *A. glabrum* and *A. alnifolia* this pathway generally encompasses *P. virginiana* and *Symphoricarpos* species.

This pathway proceeds rapidly to the large size class and high densities (Appendix M). The rapid increase in size and cover class are related to the mesic site conditions and rapid growth of these species.

Physocarpus monogynus Based Pathway

Physocarpus. monogynus is a native, deciduous shrub found from the foothills to the subalpine zone. Little information was available for *P. monogynus* and the following description is based on the similar species, *Physocarpus malvaceus*. This shrub generally grows from 2 to 7 feet tall and is found in mesic *Pinus ponderosa* and *Pseudotsuga menziesii* sites, as well as mixed conifer sites up to 10,000 feet. Cover and height of *P.* species decrease with increased forest canopy cover. *Physocarpus* species sprout following fire and are noted as fire resistant (Habeck 1992).

Physocarpus monogynus is the only species represented by this pathway. This pathway increases from small to medium size class in one decade, progressing to cover class 3 medium size class and cycles (Appendix M). The *P. monogynus* pathway represents a species of typically moderate cover and stature.

Purshia tridentata Based Pathway

Purshia tridentata is a native deciduous shrub found on all slopes and aspects. *P. tridentata* has two common ecotypes, found in the CFR. One form is a multi-stemmed, decumbent plant, while the other is a single-stemmed columnar plant. *P. tridentata* is a long lived plant with individuals reported up to 128 years-old. Regeneration of *P. tridentata* includes seed establishment, stem layering (decumbent variety only), and limited sprouting. *P. tridentata* reaches seed producing age after 8 to 10 years depending on local conditions. Rodent caches of seeds are often crucial to the *P. tridentata* regeneration (Zlatnik 1999). In Colorado, Erdman (1969) found *P. tridentata* to be a seral species in pinyon-juniper stands of the Mesa Verde. Others have noted the shade

intolerance and ability of *P. tridentata* to colonize disturbed sites (Zlatnik 1999). Austin and Urness (1983) found that in climax communities approaching 70 years old stands become decadent and productivity declines.

Purshia tridentata is easily killed by fire, but Blaisdell and Mueggler (1965) reported *P. tridentata* as a weak sprouter. *P. tridentata* occurs in communities with a variety of fire regimes. Fuel loading in *Artemisia-Purshia* and *Juniperus-Purshia* communities is light except in decadent stands, when combined with extremely dry windy conditions, may produce severe fire. A wide range of fire frequencies (2 to 300 years) has been proposed for communities associated with *P. tridentata* (Zlatnik 1999). As with *Artemisia* communities, *Bromus tectorum* invasion will increase fine fuel loads and increase fire frequency. Furthermore, studies have concluded that annual plant competition limits the survival and growth rates of emergent *P. tridentata* seedlings (Holmgren 1956, Murray 1983). Studies have shown recovery of *P. tridentata* takes too long to make fire a useful tool in managing *P. tridentata.* In Idaho it took from 15 to 20 for the community to recover. However, in both Oregon and Washington after nearly 30 years *P. tridentata* densities were lower than pre-burn densities (Zlatnik 1999).

The *Purshia tridentata* pathway represents three upland shrub combinations (table 70). *P. tridentata* rarely exceeds the medium size class or cover class 3, thus there is no large size class. This pathway move from small to medium size in one decade, however there is a delay in moving from cover class 2 to 3 due to the 8 to 10 years needed for young *P. tridentata* to produce seed. After reaching cover class 3 this pathway cycles (Appendix M).

Table 70: Species Represented by the *Purshia tridentata* Pathway Logic.

SIMPPLLE Code	Species Name
PUTR2	*Purshia tridentata*
PUTR2-ARTRV	*Purshia tridentata-Artemisia tridentata* ssp. *vaseyana*
PUTR2-RIBES	*Purshia tridentata-Ribes* species

Quercus gambelii Based Pathway

Quercus gambelii is a native shrub that often forms clones to establish dense patches ranging from 3 to 20 feet tall. It is a long-lived, drought resistant shrub living up to 120 years old. The growth rate of *Q. gambelii* decreases with age (Barger and Ffolliott 1972). While *Q. gambelii* reproduces both by seed and by sprouting, it relies more strongly on vegetative reproduction (Simonin 2000). In southern Colorado Brown (1958) found *Q. gambelii* to be secondary successional species in association with *Pinus ponderosa* and *Pseudotsuga menziesii* stands removed by fire or logging. Engle and others (1983) found *Q. gambelii* to be a persistent subclimax to conifers or a climax species in the foothills. In the absence of fire *Q. gambelii* stands reach maturity in 60 to 80 years at which point natural die-off begins, this creates more openings for sprouts (Simonin 2000).

Quercus gambelii is a fire-adapted species; prolific sprouting following fire assists the recovery of these shrub communities. Sprouting stems may reach up to 18 inches high 1 year following a fire. Depending on the fire intensity and frequency a grass-forb stage may occur (Simonin 2000). Wright (1972) predicted continuous growth following fire leading to a community matching the pre-fire community 18 years after the fire.

The *Quercus gambelii* pathway represents six *Quercus* species combinations (table 71). This pathway increases rapidly from a small size class/cover class 1 to a

medium size class/cover class 2. The pathway then increases to the large size class/cover class 3. This state represents the majority of the stands found in the GIS coverage (maximum cover 70% with an average cover of 31%). Two decades are required to move from cover class 2 to 3 and from the medium size class to the large size class, thus addressing the decrease in growth following the first few years post-disturbance (Appendix M).

Table 71: Species Represented by the *Quercus gambelii* Pathway Logic.

SIMPPLLE Code	Species Name
QUGA	*Quercus gambelii*
QUGA-AMAL2	*Quercus gambelii-Amelanchier alnifolia*
QUGA-ARUV	*Quercus gambelii-Arctostaphylos uva-ursi*
QUGA-CEMO2	*Quercus gambelii-Cercocarpus montanus*
QUGA-JUCO6	*Quercus gambelii-Juniperus communis*
QUGA-SALIXU	*Quercus gambelii*-upland *Salix* species
QUGA-VASC	*Quercus gambelii-Vaccinium scoparium*

Ribes Species Based Pathways

The description of the *Ribes* species pathways is based on *Ribes cereum*. *Ribes* is a native deciduous shrub. *R. cereum* is often found on dry, open slopes and is shade intolerant. Thus, the species is found on early seral communities and decreases as the overstory cover increases. *Ribes* plays and important role in shading conifer seedlings on open sites. *Ribes* species reproduce mainly by seed, and are described as having a weak ability to sprout. It takes three years for the species to seed and the seeds require a scarification treatment to germinate. Seed may remain viable in the soil for years (Marshall 1995b).

Ribes are often killed by fire and due to their weak sprouting ability rely on soil-stored seeds for regeneration (Marshall 1995b). Quick (1962) found *Ribes* developed more rapidly and fruited earlier on severely burned areas as opposed to partially burned thickets.

The *Ribes* pathway represents four upland shrub species combinations (table 72). Similar to *Physocarpus monogynus,* this pathway increases from small to medium size class in one decade, progressing to cover class 2 medium size and cycles (Appendix M). Therefore, this pathway represents species of typically lower cover and stature.

Table 72: Species Represented by the *Ribes* Species Pathway Logic.

SIMPPLLE Code	Species Name
RIBES	*Ribes species*
RIBES-PUTR2	*Ribes species-Purshia tridentata*
RICE	*Ribes cereum*
SHCA	*Shepherdia canadensis*

Salix glauca Based Pathway

Salix glauca is a native deciduous shrub commonly growing from 3 to 4 feet tall. On exposed sites and in alpine conditions it takes a semiprostrate form. The primary form of reproduction for *S. glauca* is by seed, however it does sprout from the root crown following fire or other disturbances and is thus a fire adapted species. Forest litter generally inhibits the germination of *S. glauca* seedlings. Dorn (1977) noted the distribution of *S. glauca* in the Rocky Mountains as being limited to well-drained sites in alpine and subalpine communities. *S. glauca* is an early seral species and is eventually displaced if an overstory canopy develops due to its low shade tolerance. Wind-dispersed seed of *S. glauca* is important in colonizing burned sites (Uchytal 1992).

Salix glauca is a fire adapted species, sprouting from the root crown following fire. This pathway represents only *S. glauca*. The pathway progresses rapidly to cover class 3 medium size class stand and cycles (Appendix M). It is assumed that this species will either be in harsh subalpine or alpine situation and as such will dominate the site.

Riparian Salix Species Based Pathways

Due to the lack of detail in the GIS coverage available for the study area, the following description of riparian *Salix* species pathways will be based on *Salix exigua*, a common riparian species. *S. exigua* is a deciduous shrub or small tree that may form thickets through root suckers. Although vegetative reproduction is important, especially with disturbed sites, seed production tends to be more important for establishing stands. *S. exigua* is a pioneer species, often replaced by cottonwoods. It is found adjacent to watercourses or on well-drained, moist benches and bottomlands. This species is shade intolerant and is often only present approximately 10 years before overstory species begin to shade them out. Associated species include *Betula occidentalis* and *Alnus incana* spp. *tenuifolia* (Uchytal 1989c).

Salix exigua sprouts following fire, and prolific seeding allows for rapid colonization of adjacent disturbed sites. These stands may also act as a firebreak due to the moist soils and high moisture content of the vegetation (Uchytal 1989c).

The riparian *Salix* pathway represents three shrub species combinations (table 73). This pathway proceeds rapidly throughout all possible size and cover classes to finally cycle in a large structured cover class 4 stand (Appendix M). Available moisture and the lack of overstory competition allow this pathway to progress rapidly through the various states.

Table 73: Species Represented by the Riparian *Salix* Species Pathway Logic.

SIMPPLLE Code	Species Name
SALIX	Riparian *Salix* species
SALIX-ALINT	*Salix* species-*Alnus incana spp. tenuifolia*
SALIX-BEOC2	*Salix* species-*Betula occidentalis*

Upland Salix Species Based Pathway

Due to the lack of detail in the GIS coverage available for the study area, the following description of upland *Salix* species pathways will be based on *Salix scouleriana*, a common upland species. *S. scouleriana* is a tall shrub or small tree growing to 35 feet tall and having many to one main stem. This upland *Salix* species is found in a large range of sites from swamps to high elevation rocky areas. It most commonly occurs as scattered individuals in open canopy forests and transition zones from riparian areas to upland areas (Anderson 2001c).

Salix scouleriana is common in open areas following disturbance due to its ability to resprout from the root crown, and windborne seeds (Weaver 1917, as cited in Mueggler 1965). Mueggler (1965) found *S. scouleriana* benefited from burning in Idaho and substantially higher frequency and cover of *S. scouleriana* occurred on sites with <25% forest canopy cover. While *S. scouleriana* is shade intolerant, it maintains small populations under thick forest cover as a persistent seral species (Anderson 2001c). In a northern Idaho study *S. scouleriana* was found to reach peak cover values within eight years (Stickney 1986). However, another Idaho study found *S. scouleriana* achieved its maximum frequency and cover in stands from 20 to 30 years old (Mueggler 1965).

Two species combinations are represented by the upland *Salix* pathway (table 74). While this pathway progresses rapidly through the various size and cover classes, the pathway cycles with a large size class, cover class of 3 (Appendix M). The cover class 4 pathway is available for post-disturbance sites. Limiting the pathway progression at cover class 3 reflects the interaction of this species with overstory cover.

Table 74: Species Represented by the Upland *Salix* Species Pathway Logic.

SIMPPLLE Code	Species Name
SALIXU	Upland *Salix* species
SALIXU-RIBES	Upland *Salix* species-*Ribes* species

Vaccinium myrtillus Based Pathways

Vaccinium myrtillus is a native rhizomatous shrub growing to 18 inches tall. *V. myrtillus* generally lives to 15 years old and can reproduce by seed, but reproduction occurs primarily through its extensive rhizome network. *V. myrtillus* occurs in open woods, high ridges and moraines, as well as in climax *Picea engelmannii-Abies lasiocarpa* and *Pinus contorta* stands in Colorado (Clagg 1975).

Vaccinium myrtillus is adapted to both high and low frequency fire regime because of sprouting from the surviving rhizomes following fire (Tirmenstein 1990). Clagg (1975) found *V. myrtillus* to establish understory dominance nearly 100 years following fire. Regeneration by seed is poor due to the low viability and their heat sensitive nature (Tirmenstein 1990).

The *Vaccinium myrtillus* pathway represents two species combinations (table 75). This pathway remains in the small size class throughout its progression, but does reach cover class 3 (Appendix M). The cover class progression of this pathway is slowed in cover class 2, requiring 2 decades to progress, to capture the moderate rhizomatous growth of this species.

Table 75: Species Represented by the *Vaccinium myrtillus* Pathway Logic.

SIMPPLLE Code	Species Name
VAMY2	*Vaccinium myrtillus*
VASC	*Vaccinium scoparium*

Pinus edulis-Juniperus scopulorum Pathway

Pinus edulis-Juniperus scopulorum woodland type is found on foothills, low mountains, mesas, and plateaus from elevation of 4,000 to 8,000 feet throughout its range (Evans 1988). This woodland type is slow growing (table 76), and depends exclusively on seed production and dispersal for stand maintenance (Anderson 2002).

Table 76: *Pinus monophylla-Juniperus osteosperma* Growth Rates in East-central Nevada.

Size class	Age (yrs)		Basal Diameter cm (in.)		Height cm (in.)	
	Pinyon	Juniper	Pinyon	Juniper	Pinyon	Juniper
Seedling	7	10	.5 (.19)	.5 (.19)	15 (5.9)	15 (5.9)
Young Seedling	28	45	3 (1.18)	3 (1.18)	70 (27.56)	73 (28.74)
Sapling	45	84	6 (2.36)	6 (2.36)	158 (62.20)	158 (62.20)
Mature vigorous	73	97	15 (5.9)	12 (4.7)	334 (131.49)	303 (119.29)
Mature old	102	137	24 (9.44)	16 (6.299)	477 (187.79)	389 (153.14)

Source: Blackburn and Tueller 1970.

Regeneration of *P. edulis-J.* species stands are limited by microsite conditions, the presence of nurse plants, chemical reactions among plants and competition between plants (Evans 1988). Evans (1988) reported good seed production in *P. edulis* trees from 75 to 100 years old, but maximum seed production likely occurs in tree from 160 to 200 years old. In contrast, *J. scopulorum* may produce seed from 10 to 20 years old but maximum seed production is from 50 to 200 years old. Furthermore, while *J. scopulorum* is capable of seed production every year, large seed crops occur every 2 to 5 years (Scher 2002). Birds and rodents are the main agents of seed dispersal; carrying up to 30,000 seeds 6 miles a day (Evans 1988). The need of nurse plants for the survival of *P. edulis* seedlings has been widely reported (Everett 1987, Gottfried 1987, Evans 1988). Although *P. edulis* is shade intolerant, canopy cover on these sites is generally sparse and the microenvironment created by the nurse plant moderates temperature and available soil moisture. In Oregon and Utah *Juniperus occidentalis* seedlings were found primarily

under the canopies of *Artemisia* species and other established *Juniperus* species (Evans 1988, Barney and Frischknecht 1974).

It appears that *Pinus edulis-Juniperus* invasion into grasslands is affected by herbaceous competition. Blackburn and Tueller (1970) reported that the invasion of these woodland species into grasslands occurred in concert with above normal, near normal, and slightly below normal precipitation years. Thus, herbaceous species would not have been stressed by drought, on the contrary herbaceous competition may have increased in these communities. It is possible that during wet years moisture related competition is sufficiently reduced to allow the establishment of *Juniperus* in the thickest herbaceous stands (Johnsen 1962, as cited in Blackburn and Tueller 1970).

Several successional models have been proposed for *P. edulis-Juniperus* species woodlands. In Colorado Erdman (1969) documented a generalized successional model for this woodland type progressing from a skeletal forest to climax conditions (figure 6).

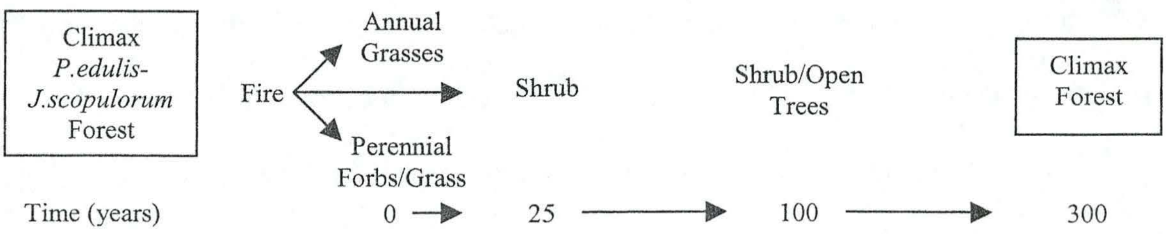
Figure 6: Erdman (1969) *Pinus edulis-Juniperus* Species Successional Model.

Climax *P.edulis-J.scopulorum* Forest	Fire	Skeleton Forest	Annual Grasses	Perennial Forbs/Grass	Shrub	Shrub/Open Trees	Climax Forest
Time (years)		0 →	2 →	4 →	25 →	100 →	300

While useful, this generic view of succession in *P. edulis-Juniperus* species stands has been challenged. Everett and Ward (1984) proposed a modification to the Erdman model, suggesting the "initial floristic" succession model of Egler (1954, as cited by Everett and Ward 1984, Tausch and others 1981, Koniak 1985) better described these

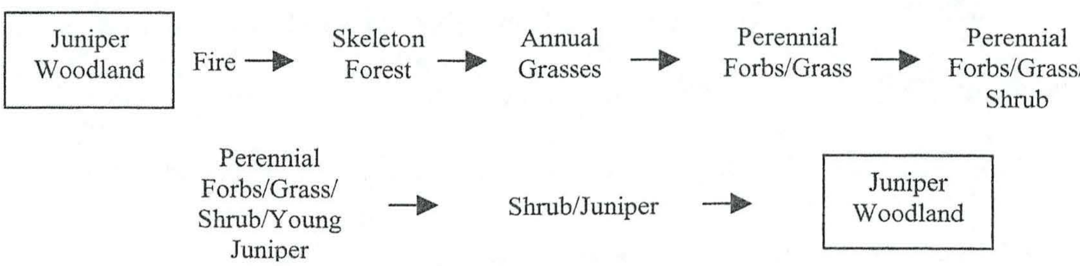
systems. As a result, Everett and Ward (1984) modified the successional model of Erdman (1969) to represent multiple post-fire communities (figure 7).

Figure 7: Everett and Ward (1984) *Pinus edulis-Juniperus* Species Successional Model.



An additional succession model has been proposed for west-central Utah (Barney and Frischknecht 1974) (figure 8).

Figure 8: Barney and Frischknecht (1974) *Pinus edulis-Juniperus* Species Successional Model.



Barney and Frischknecht (1974) found the annual stage reached maximum development in post-fire year 3 or 4, and was replaced by perennial grasses by post-fire year 5 or 6 if there was a fair remnant of native grasses in the pre-burn community. The shrub stage, in this case *Artemisia* species, began developing at post-fire year 11 but did not reach site dominance until year 35. Similarly, *Juniperus* occurred in year 11 but did not establish site dominance until approximately year 70. *P. edulis* occurred in minor amounts in the oldest stands (100+ years) and as such was not considered as part of the post-fire community (Barney and Frischknecht 1974).

Pinus edulis and *J. scopulorum* are sensitive to fire and may be readily killed by fire when trees are less than 4 feet tall. However, as both species mature they become more resistant to fire (Evans 1988, Scher 2002) and as *P. edulis-J.* species begin to dominate a site it becomes more resistant to fire. Juniperus dominated stands compete directly with understory vegetation. As competition increases there is a subsequent reduction in herbaceous species reduces the fine fuels required to carry a ground fire (Bunting 1987).

The *P. edulis-J. scopulorum* pathway represents seven species combinations (table 77). As with the growth of *P. edulis-J. scopulorum* trees, the pathway progresses slowly through each size and cover class taking 30 years to move from saplings to the medium size class. Medium size class stands require 50 years to proceed to the large size class for a total of 80 years. Because good seed production occurs in *Juniperus* species from 50 years and over 100 years in *P. edulis* over 100 years is required to increase canopy cover in this pathway (Appendix M).

Table 77: Species Represented by the *Pinus edulis-Juniperus* Species Pathway Logic.

SIMPPLLE Code	Species Name
JUMO	*Juniperus monosperma*
JUMO-PIED	*Juniperus monosperma-Pinus edulis*
JUSC2	*Juniperus scopulorum*
JUSC2-PIED	*Juniperus scopulorum-Pinus edulis*
PIED	*Pinus edulis*
PIED-JUMO	*Pinus edulis-Juniperus monosperma*
PIED-JUSC2	*Pinus edulis-Juniperus scopulorum*

Forest Pathways

Through the integration of GIS data and Colorado habitat type classifications 95 forest pathways were delineated (Appendix J). While a detailed discussion of the these pathways is beyond the scope of this report it should be noted that the forested pathways

for the CFR were based on those completed for the eastside of the Continental Divide in Region One. However, a direct translation of the time between structural changes was not appropriate because the size class resulting from the Colorado GIS data does not match that of Region One (table 78). Therefore, adjustments were made to the pathways in an effort to maintain consistency across system versions.

Table 78: Comparison of Colorado and Eastside Region One Forest Size Classes.

Size Classes	**Colorado Definition** (inches)	**Eastside Region One Definition**[1] (inches)
Established Seedling	0.0-0.9	N/A
Sapling	1.0-4.9	0.0-4.9
Pole	N/A	5.0-8.9
Medium	5.0-8.9	9.0-14.9
Large	9.0-15.9	15.0-20.9
Very Large	>16.0	>21

[1] User's Guide for SIMPPLLE ver. 2.3.

Regeneration Logic

The concept of species and/or structural change in SIMPPLLE requires the use of several different system components. Because this LDSS is spatially explicit, the pathways contain only the knowledge relevant to the species or species combination at hand. Knowledge regarding neighboring plant communities is contained within several different compartments of the system (Chew 2004). One of these components is the regeneration logic table. Regeneration in SIMPPLLE is handled as a process and relies on spatially explicit information. Regeneration logic is referenced under two scenarios: 1) following a stand-replacing fire (fire regeneration); and, 2) when non-forested sites exist on a forested habitat type (succession regeneration) (Chew and others 2003). Fire regeneration is further separated into five components used to determine the seed source from which a community can regenerate. The five components in order of importance

are: resprouting, adjacent resprouting, in place seed, in landscape seed, and adjacent seed sources.

Sprouting regeneration was developed for *Populus tremuloides* and *Populus angustifolia* in Region One and is used for the CFR. The inclusion of the shrub pathways in the CFR system applies the same logic to 16 shrub species (Appendix E). Furthermore, it is assumed all graminoids in the CFR version experience stand-replacing fire resulting in the removal of above ground biomass. Therefore, all graminoids except *Bromus tectorum*, an annual species reproducing solely by seed, are capable of resprouting from the remaining root crown except in cases of extreme soil scorch. As a result, graminoid communities will regain their pre-fire character shortly after disturbance events.

Adjacent resprouting is a combination of a species resprouting in an adjacent community and available seed crop for that species (Chew and others 2003). This regeneration logic was developed for *Populus tremuloides* and *Populus angustifolia* stands in earlier system versions. However, the CFR version of SIMPPLLE extends this logic to include graminoid species, which reproduce vegetatively such as *Poa pratensis*. The combination of vegetative growth and viable seed will revegetate adjacent sites, granted it will take longer than if existing species were to resprout on site. Thirteen graminoid species combinations are capable of adjacent resprouting (table 79). Shrub species were not considered for this type of regeneration because most shrub species sprout from the root crown.

Table 79: Species Represented by Adjacent Resprouting Regeneration Logic.

SIMPPLLE Code	Species Name
BOGR2	*Bouteloua gracilis*
CACA4	*Calamagrostis canadensis*
CAEL3-CARUD	*Carex elynoides-Carex rupestris*
CAFO3	*Carex foenea*
CAREX	*Carex* species
CAREX-JUNCO	*Carex-Juncus* species
CAREXU	upland *Carex* species
CAREXU-CARU	upland *Carex-Calamagrostis rubescens*
CARO5	*Carex rossii*
CARUD-FEBRC	*Carex rupestris-Festuca brachyphylla*
JUBAL-CAGE2	*Juncus balticus-Carex geyeri*
PASM	*Pascopyrum smithii*
POPR	*Poa pratensis*

Seed from on site refers to species, which produce viable seed that is capable of surviving a fire event. The CFR SIMPPLLE version assumes that all bunchgrasses, and *Bromus tectorum,* will have some fraction of surviving seed following all but the most severe fire intensities. Eighteen graminoid and nine shrub species combinations are capable of establishing from in-place seed (table 80).

Landscape seed source logic was developed to reflect the dispersal of *Pinus flexilis* and *Pinus albicaulis* by birds (Chew and others 2003). We used the same logic for *Pinus edulis, Juniperus scopulorum,* and *Juniperus monosperma* for the CFR. Evans (1988) documented the effectiveness of this method of seed dispersal noting birds will carry up to 30,000 *P. edulis* and *Juniperus* seeds 6 miles a day.

Seed from adjacent communities in CFR version of SIMPPLLE is provided for situations in which none of the prior regeneration strategies apply to a site. SIMPPLLE evaluates adjacent communities, which are producing seed, and populates the site based on the species with the largest adjacent acreage (Chew and others 2003). This process is well suited for non-sprouting species that rely on adjacent communities as a seed source.

Nine species combinations are capable of establishing via adjacent community seed sources (table 81).

Table 80: Species Represented by On-Site Seed Regeneration Logic.

Lifeform	SIMPPLLE Code	Species Name
G	ACHY	*Achnatherum hymenoides*
G	BRTE	*Bromus tectorum*
G	CAGE2	*Carex geyeri*
G	CAPU	*Calamagrostis purpurascens*
G	FEAR2	*Festuca arizonica*
G	FEAR2-BOGR2	*Festuca arizonica-Bouteloua gracilis*
G	FEAR2-DAPA2	*Festuca arizonica-Danthonia parryi*
G	FEAR2-MUMO	*Festuca arizonica-Muhlenbergia montana*
G	FEID	*Festuca idahoensis*
G	FETH	*Festuca thurberi*
G	HECO26	*Hesperostipa comata*
G	LEKI2	*Leucopoa kingii*
G	MUMO	*Muhlenbergia montana*
G	PHCO9-POAL2	*Phleum alpinum-Poa alpina*
G	POAL2-CAEL3	*Poa alpina-Carex elynoides*
G	POAL2-KOMY	*Poa alpina-Kobresia myosuroides*
G	POFE	*Poa fendleriana*
G	PSSP6	*Pseudoroegneria spicata*
S	ARTR2	*Artemisia tridentata*
S	ARTRV	*Artemisia tridentata ssp. vaseyana*
S	ARTRV-PUTR2	*Artemisia tridentata ssp. vaseyana-Purshia tridentata*
S	ARTRW8	*Artemisia tridentata ssp. wyomingensis*
S	PUTR2	*Purshia tridentata*
S	PUTR2-ARTRV	*Purshia tridentata-Artemisia tridentata*
S	RIBES	*Ribes* species
S	RIBES-PUTR2	*Ribes* species-*Purshia tridentata*
S	RICE	*Ribes cereum*

Table 81: Species Represented by Adjacent Seed Source Regeneration Logic.

Lifeform	SIMPPLLE Code	Species Name
G	BRTE	*Bromus tectorum*
S	ARTR2	*Artemisia tridentata*
S	ARTR2-JUCO6	*Artemisia tridentata-Juniperus communis*
S	ARTRV	*Artemisia tridentata ssp. vaseyana*
S	ARTRV-PUTR2	*Artemisia tridentata ssp. vaseyana-Purshia tridentata*
S	ARTRW8	*Artemisia tridentata ssp. wyomingensis*
S	JUCO6	*Juniperus communis*
S	PUTR2	*Purshia tridentata*
S	PUTR2-ARTRV	*Purshia tridentata-Artemisia tridentata*

Summary and Conclusions

This report catalogs the methods and assumptions used to build successional pathways and regeneration logic for forest and non-forest species along the CFR. The pathways are based on published research, other literature including habitat type manuals, and existing versions of the LDSS SIMPPLLE. The task was challenging considering the ecological and spatial amplitude of the research area, the number of species modeled, and in general, a lack of long-term ecological monitoring following various disturbances for many of the species. Despite these challenges, we believe the CFR version of SIMPPLLE will be capable of capturing the interactions between species combinations throughout six ecological zones along the east-slope of the Colorado Rockies

In our review of literature it was apparent that there is a dearth of ecological information, especially for non-forest species. For example, in many studies basic ecological information such as average time required for an ecological site to regain its post-disturbance character was not available. Moreover, specific studies were often limited in geographic extent. As a result, information gathered on a study in Utah or Idaho would have to be extrapolated to the conditions existing along the CFR for the purpose of this system version. Because species response to disturbance is often linked to the specific circumstances present at the time of treatment, some studies provided conflicting results, or results so vague they were of little use. For example, the fire return intervals summarized for *Artemisia tridentata* ssp. *wyomingensis* range from 10 to 70 years (Howard 1999). These gaps and inconsistencies in the literature suggest a strong need for renewed ecological research on successional change.

The treatment and documentation of non-forest types for this version of SIMPPLLE is an improvement over previous versions. This project provides a thorough review of non-forest species, their interactions, and the logic need to capture the disturbance processes specific to these ecological sites. While we have provided an extensive literature review in regards to the dominant non-forest species important to the CFR, there is still need for more detailed information on system processes specific to non-forest communities. For example, it was necessary for processes such as wildlife browsing to be treated coarsely because of a lack of information. There is no doubt that additional information and refined logic, which will require additional research studies, would improve future versions. Furthermore, we believe that for the non-forest types current information on species interactions could be improved with linking ecological site information to future SIMPPLLE versions. The Natural Resources Conservation Service has developed ecological site guides, which characterize dominant "climax" vegetation by soil type and precipitation zone. This information, while in draft form for Colorado (Kot 2003), would be beneficial in describing these non-forest communities.

It is important that the CFR version now undergo review by ecologist and managers that have experience and sound knowledge of the region and its characteristics. While the ecological stratification by zone has been used for several other ecological applications (Peet 1978), this stratification may not be fine enough to capture species interactions documented in the habitat type manuals for Colorado. Moreover, the GIS data being collected does not result in habitat type classifications and thus there is a loss of stand specific information found in habitat type manuals. By including ecologists and managers invested in this area, we may identify the need for supplemental GIS data to

link with the habitat type classifications. We may also identify the need to create a north and south version of the system to deal with the latitudinal changes that occur in vegetation along the CFR. A review of the CFR version of SIMPPLLE will increase communication among the stakeholders in this process and provide valuable insight to the priorities and needs of a LDSS for the CFR.

The cooperative agreement between the RMRS and The University of Montana provided for the completion of test simulations to assess the behavior of the CFR version of SIMPPLLE. Due to external circumstances this was not accomplished. When simulations are initiated we suggest examining the ecological response of big sagebrush stands to fire suppression and the subsequent reintroduction of fire. The various subspecies of big sagebrush are found in different ecological settings and are prone to pinyon-juniper invasion at lower elevations, and pine invasion at higher elevations. Furthermore, big sagebrush relies on seed for post-fire recovery, thus providing a good opportunity to examine the regeneration logic within the system. While this is not a definitive test of system behavior, simulations such as this would provide insight into the interactions of the various SIMPPLLE components.

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Appendices

Appendix A: Colorado Front Range Dominant Species by Ecological Zone

Ecological Zone	Scientific Name	Common Name
Alpine	*Abies lasiocarpa*	subalpine fir
	Artemisia scopulorum	alpine sagebrush
	Carex elynoides	blackroot sedge
	Carex foenea	dryspike sedge
	Carex rupestris	Drummond's sedge
	Carex species	sedge species
	Castilleja occidentalis	western Indian paintbrush
	Dasiphora floribunda	shrubby cinquefoil
	Phleum alpinum	alpine timothy
	Pinus aristata	bristlecone pine
	Pinus contorta	lodgepole pine
	Picea engelmannii	Engelmann spruce
	Pinus flexilis	limber pine
	Poa alpina	alpine bluegrass
	Populus tremuloides	quaking aspen
	Pseudotsuga menziesii	Douglas-fir
	Salix arctophila	northern willow
	Salix glauca	grayleaf willow
	Salix species	willow species
	Silene acaulis	moss campion
	Vaccinium myrtillus	whortleberry
	Vaccinium scoparium	grouse whortleberry
Subalpine	*Abies concolor*	white fir
	Abies lasiocarpa	subalpine fir
	Arnica cordifolia	heartleaf arnica
	Artemisia scopulorum	alpine sagebrush
	Artemisia tridentata	big sagebrush
	Arctostaphylos uva-ursi	kinnikinnick
	Carex foenea	dryspike sedge
	Carex geyeri	elk sedge
	Carex species	sedge species
	Cercocarpus montanus	alderleaf mountain mahogany
	Dasiphora floribunda	shrubby cinquefoil
	Juncus balticus	Baltic rush
	Juniperus communis	common juniper
	Juniperus scopulorum	Rocky Mountain juniper
	Pinus aristata	bristlecone pine
	Pinus contorta	lodgepole pine
	Pinus edulis	two-needle pinyon
	Picea engelmannii	Engelmann spruce
	Pinus flexilis	limber pine
	Pinus ponderosa	ponderosa pine
	Pinus pungens	blue spruce
	Populus angustifolia	narrowleaf cottonwood
	Populus deltoides	plains cottonwood
	Populus tremuloides	quaking aspen
	Pseudotsuga menziesii	Douglas-fir
	Purshia tridentata	antelope bitterbrush
	Quercus gambelii	Gambel oak
	Salix glauca	grayleaf willow

Ecological Zone	Scientific Name	Common Name
	Salix species	willow species
	Senecio species	ragwort species
	Silene acaulis	moss campion
Subalpine Cont.	*Thalictrum dioicum*	early meadow-rue
	Trifolium species	clover species
	Vaccinium myrtillus	whortleberry
	Vaccinium scoparium	grouse whortleberry
	Abies concolor	white fir
	Abies lasiocarpa	subalpine fir
	Alnus incana ssp. *tenuifolia*	thinleaf alder
	Artemisia tridentata	big sagebrush
	Arctostaphylos uva-ursi	kinnikinnick
	Carex species	sedge species
	Cercocarpus montanus	alderleaf mountain mahogany
	Dasiphora floribunda	shrubby cinquefoil
	Juniperus communis	common rush
	Juniperus scopulorum	Rocky Mountain juniper
	Pinus contorta	lodgepole pine
Upper Montane	*Pinus edulis*	two-needle pinyon
	Pinus engelmannii	Engelmann spruce
	Pinus flexilis	limber pine
	Pinus ponderosa	ponderosa pine
	Picea pungens	blue spruce
	Populus angustifolia	narrowleaf cottonwood
	Populus tremuloides	quaking aspen
	Pseudotsuga menziesii	Douglas-fir
	Purshia tridentata	antelope bitterbrush
	Quercus gambelii	Gambel oak
	Ribes cereum	wax current
	Salix species	willow species
	Abies concolor	white fir
	Alnus incana ssp. *tenuifolia*	thinleaf alder
	Artemisia tridentata	big sagebrush
	Arctostaphylos uva-ursi	kinnikinnick
	Betula occidentalis	water birch
	Carex species	sedge species
	Cercocarpus montanus	alderleaf mountain mahogany
	Juniperus communis	common rush
	Juniperus scopulorum	Rocky Mountain juniper
	Pinus contorta	lodgepole pine
Lower Montane	*Pinus edulis*	two-needle pinyon
	Pinus engelmannii	Engelmann spruce
	Pinus flexilis	limber pine
	Pinus ponderosa	ponderosa pine
	Picea pungens	blue spruce
	Populus angustifolia	narrowleaf cottonwood
	Populus deltoides	plains cottonwood
	Populus tremuloides	quaking aspen
	Pseudotsuga menziesii	Douglas-fir
	Quercus gambelii	Gambel oak
	Ribes species	current species
	Salix species	willow species

Ecological Zone	Scientific Name	Common Name
Foothills	*Arctostaphylos uva-ursi*	kinnikinnick
	Cercocarpus montanus	alderleaf mountain mahogany
	Juniperus communis	common juniper
	Juniperus scopulorum	Rocky Mountain juniper
	Pinus contorta	lodgepole pine
	Pinus contorta	lodgepole pine
	Pinus edulis	two-needle pinyon
	Pinus engelmannii	Engelmann spruce
	Pinus ponderosa	ponderosa pine
	Picea pungens	blue spruce
	Populus angustifolia	narrowleaf cottonwood
	Populus tremuloides	quaking aspen
	Pseudotsuga menziesii	Douglas-fir
	Quercus gambelii	Gambel oak
	Salix species	willow species
Plains[1]	*Pinus engelmannii*	Engelmann spruce
	Pseudotsuga menziesii	Douglas-fir

Source: Common vegetation unit GIS data for Region 2

[1] Plains query returned primarily records with elevation equal to zero.

Appendix B: North Habitat Types

Dominant Overstory	Shrubs	Grasses
Juniperus scopulorum	*Cercocarpus montanus*	*Hesperostipa comata*
	Purshia tridentata	*Muhlenbergia montana, Carex rossii*
	Artemisia tridentata	*Achnatherum hymenoides*
Pinus ponderosa	*Cercocarpus montanus*	*Carex rossii*
	Purshia tridentata	*Leucopoa kingii, Muhlenbergia montana*
		Muhlenbergia montana
		Leucopoa kingii
		Carex rossii
Pseudotsuga menziesii	*Physocarpus monogynus*	*Leucopoa kingii*
	Jamesia americana	*Carex rossii*
		Carex geyeri
		Carex rossii
Populus tremuloides		*Festuca thurberi*
		Carex geyeri
Pinus flexilis	*Juniperus communis*	*Calamagrostis purpurascens, Carex rossii*
		Calamagrostis purpurascens
Pinus contorta	*Juniperus communis*	*Calamagrostis purpurascens, Carex rossii*
	Shepherdia canadensis	*Carex geyeri, Carex rossii*
	Vaccinium scoparium	*Carex geyeri*
		Carex geyeri
Picea engelmannii		*Calamagrostis purpurascens*
Abies lasiocarpa	*Vaccinium scoparium*	*Carex rossii, Calamagrostis canadensis*
		Carex geyeri
		Calamagrostis canadensis
Pinus aristata		*Calamagrostis purpurascens, Carex foenea*
Populus angustifolia	*Salix* spp., *Acer glabrum*	*Calamagrostis canadensis*
Picea pungens		*Carex foenea, Calamagrostis canadensis, Poa pratensis*

Sources: Hess and Alexander, 1986; Alexander, 1987.

Appendix C: South Habitat Types

Dominant Overstory	Shrubs	Graminoids
Abies concolor	*Vaccinium myrtillus*	*Carex rossii*
	Acer glabrum	*Carex rossii, Poa fendleriana*
	Arctostaphylos uva-ursi	*Muhlenbergia montana, Poa fendleriana*
	Quercus gambelii	*Carex rossii, Poa fendleriana*
		Festuca arizonica, Danthonia parryi
Pinus ponderosa	*Arctostaphylos uva-ursi*	*Festuca arizonica, Muhlenbergia montana*
	Quercus gambelii	*Carex geyeri, Festuca arizonica*
		Festuca arizonica
		Muhlenbergia montana
		Bouteloua gracilis
		Achnatherum hymenoides
		Poa pratensis
Pseudotsuga menziesii	*Quercus gambelii*	*Poa fendleriana, Carex geyeri*
		Festuca arizonica
Populus tremuloides	*Arctostaphylos uva-ursi*	*Carex foenea*
	Juniperus communis	*Carex foenea, Poa pratensis*
	Physocarpus monogynus	*Carex geyeri*
	Shepherdia canadensis	*Carex foenea*
		Festuca thurberi
		Poa pratensis
		Carex foenea
Pinus flexilis	*Arctostaphylos uva-ursi*	*Carex rossii*
Pinus contorta	*Arctostaphylos uva-ursi*	*Carex rossii*
	Juniperus communis	*Carex rossii*
	Vaccinium myrtillus	*Carex geyeri*
Picea engelmannii	*Vaccinium myrtillus*	*Carex rossii*
Abies lasiocarpa	*Vaccinium myrtillus*	*Carex rossii*
Picea aristata		*Festuca thurberi*
		Festuca arizonica
Picea pungens	*Arctostaphylos uva-ursi*	*Carex rossii, Muhlenbergia montana*
		Carex foenea
		Festuca arizonica
		Poa pratensis

Source: DeVelice and others, 1986; Alexander, 1987.

Appendix D: Non-Forest Habitat Types and Associations

Dominant Overstory	Shrubs	Graminoids
Pinus edulis-Juniperus scopulorum/monosperma Type[1]	*Quercus gambelii*	*Carex geyeri*
	Cercocarpus montanus	*Achnatherum hymenoides, Bouteloua gracilis*
		Bouteloua gracilis
Cercocarpus montanus Type[1]		*Hesperostipa comata, Bouteloua gracilis*
		Muhlenbergia montana
Quercus gambelii Type[1]	Mesic Shrubs	*Carex geyeri, Poa pratensis*
	Amelanchier alnifolia	*Carex geyeri, Poa pratensis*
		Bouteloua gracilis
Juniperus scopulorum-Pseudoroegneria spicata	*Artemisia tridentata ssp. wyomingensis*	*Pseudoroegneria spicata, Achnatherum hymenoides, Bouteloua gracilis*
Artemisia tridentata ssp. wyomingensis- Juniperus scopulorum:	*Purshia tridentata*	*Pseudoroegneria spicata*
	Chrysothamnus viscidiflorus	*Achnatherum hymenoides*
Artemisia tridentata ssp. wyomingensis- Pascopyrum smithii	*Chrysothamnus viscidiflorus*	*Pascopyrum smithii, Bouteloua gracilis*
Artemisia tridentata ssp. wyomingensis-Pseudoroegneria spicata	*Chrysothamnus viscidiflorus*	*Pseudoroegneria spicata, Poa fendleriana*
Artemisia tridentata ssp. wyomingensis- Hesperostipa comata	*Chrysothamnus viscidiflorus*	*Hesperostipa comata, Pascopyrum smithii*
Artemisia tridentata ssp. vaseyana- Festuca thurberi		*Festuca thurberi, Hesperostipa comata,* upland Carex species
Artemisia tridentata ssp. vaseyana- Festuca idahoensis	Mesic Shrubs	*Festuca idahoensis, Poa fendleriana*
Purshia tridentata- Artemisia tridentata ssp. vaseyana	*Amelanchier alnifolia*	*Festuca idahoensis,* upland Carex species
Amelanchier alnifolia-Pseudoroegneria spicata		*Pseudoroegneria spicata, Achnatherum hymenoides*
Amelanchier alnifolia- upland *Carex* species	*Chrysothamnus viscidiflorus*	Upland Carex species
Ericameria parryi-Achnatherum hymenoides	*Artemisia tridentata*	*Achnatherum hymenoides*

Sources: Tiedeman and others, 1987; Johnston, 1987.

[1] Shrubs are listed with common associated shrubs and graminoids not document habitat or community types.

Appendix E: Shrub Species Attributes.

Species Code	Scientific Name	Shade Tolerance	Resprout Ability	Wildlife Browsing
ACGL	*Acer glabrum*	Intermediate	Yes	Yes
ALINT	*Alnus incana*	Intermediate	Yes	Yes
AMAL2	*Amelanchier alnifolia*	Intermediate	Yes	Yes
ARTR2	*Artemisia tridentata*	Intolerant	No	Yes
ARTRV	*Artemisia tridentata* ssp. *vaseyana*	Intolerant	No	Yes
ARTRW8	*Artemisia tridentata* ssp. *wyomingensis*	Intolerant	No	Yes
ARUV	*Arctostaphylos uva-ursi*	Intermediate	No	No
BEOC2	*Betula occidentalis*	Intermediate	Yes	Yes
CEMO2	*Cercocarpus montanus*	Intermediate	Yes	Yes
CHVI8	*Chrysothamnus viscidiflorus*	Intolerant	No	Yes
ERPA	*Ericameria parryi*	Intolerant	Yes	Yes
JAAM	*Jamesia americana*	Intolerant	Yes	No
JUCO6	*Juniperus communis*	Intolerant	No	No
PHMO4	*Physocarpus monogynus*	Intolerant	Yes	Yes
DAFL3	*Dasiphora floribunda*	Intermediate	Yes	Yes
PUTR2	*Purshia tridentata*	Intermediate	No	Yes
QUGA	*Quercus gambelii*	Intolerant	Yes	Yes
RIBES	*Ribes* species	Tolerant	Yes	Yes
RICE	*Ribes cereum*	Intolerant	Yes	Yes
SALG	*Salix glauca*	Intolerant	Yes	Yes
SALIX	*Salix* species	Intermediate	Yes	Yes
SHCA	*Shepherdia canadensis*	Intermediate	Yes	Yes
VASC	*Vaccinium scoparium*	Tolerant	Yes	No

Source: NRCS PLANTS Database and USDA Forest Service Fire Effects Information web pages.

Appendix F: Graminoid Species Attributes.

Species Code	Scientific Name	Pathway Group	Prairie Dog Invasion
ACHY	*Achnatherum hymenoides*	Low Cover	No
BOGR2	*Bouteloua gracilis*	Low Cover	Yes
BRTE	*Bromus tectorum*	High Cover	No
CACA4	*Calamagrostis canadensis*	Low Cover	No
CAGE2	*Carex geyeri*	Low Cover	No
CAPU	*Calamagrostis purpurascens*	Low Cover	No
CARO5	*Carex rossii*	Low Cover	No
CARU	*Calamagrostis rubescens*	Low Cover	No
FEAR2	*Festuca arizonica*	High Cover	No
FEID	*Festuca idahoensis*	High Cover	Yes
FETH	*Festuca thurberi*	High Cover	No
HECO26	*Hesperostipa comata*	Low Cover	Yes
LEKI2	*Leucopoa kingii*	Low Cover	No
JUBAL	*Juncus balticus*	High Cover	No
MUMO	*Muhlenbergia montana*	High Cover	No
PASM	*Pascopyrum smithii*	Low Cover	Yes
PHAL2	*Phleum alpinum*	Alpine/Riparian	No
POAL2	*Poa alpina*	Alpine/Riparian	No
POFE	*Poa fendleriana*	Low Cover	No
POPR	*Poa pratensis*	High Cover	No
PSSP6	*Pseudoroegneria spicata*	High Cover	Yes

Source: NRCS PLANTS Database and USDA Forest Service Fire Effects Information web pages.

Appendix G: Graminoid Species Combinations.

Species Code	Latin Name	Common Name
ACHY	*Achnatherum hymenoides*	indian rice grass
AG-FORBS		Annual grass-Forbs
BOGR2	*Bouteloua gracilis*	blue grama
BRTE	*Bromus tectorum*	cheatgrass
CACA4	*Calamagrostis canadensis*	blue joint
CAEL3-CARUD	*Carex elynoides-Carex rupestris*	blackroot sedge-Drummond's sedge
CAFO3	*Carex foenea*	dryspike sedge
CAGE2	*Carex geyeri*	Geyer's sedge
CAPU	*Calamagrostis purpurascens*	purple reedgrass
CAREX	*Carex* spp.	sedge species
CAREX-JUNCU	*Carex-Juncus* spp.	sedge species-rush species
CAREXU	upland *Carex* spp.	upland sedge species
CAREXU-CARU	upland *Carex-Calamagrostis rubescens*	upland sedge-pinegrass
CARO5	*Carex rossii*	Ross' sedge
CARUD-FEBRC	*Carex rupestris-Festuca brachyphylla*	Drummond's sedge-Colorado fescue
FEAR2	*Festuca arizonica*	Arizona fescue
FEAR2-BOGR2	*Festuca arizonica-Bouteloua gracilis*	Arizona fescue-blue grama
FEAR2-DAPA2	*Festuca arizonica-Danthonia parryi*	Arizona fescue-Parry's oatgrass
FEAR2-MUMO	*Festuca arizonica-Muhlenbergia montana*	Arizona fescue-mountain muhly
FEID	*Festuca idahoensis*	Idaho fescue
FETH	*Festuca thurberi*	Thurber's fescue
HECO26	*Hesperostipa comata*	needle and thread
JUBAL-CAGE	*Juncus balticus-Carex geyeri*	Baltic rush-Geyer's sedge
LEKI2	*Leucopoa kingii*	spike fescue
MUMO	*Muhlenbergia montana*	mountain muhly
PASM	*Pascopyrum smithii*	western wheatgrass
PG-FORBS		Perennial grass-Forbs
PHCO9-POAL2	*Phleum alpinum-Poa alpina*	alpine timothy-alpine bluegrass
POAL2-CAEL3	*Poa alpina-Carex elynoides*	alpine bluegrass-blackroot sedge
POAL2-KOMY	*Poa alpina-Kobresia myosuroides*	alpine bluegrass-Bellardi bog sedge
POFE	*Poa fendleriana*	mutton grass
POPR	*Poa pratensis*	Kentucky bluegrass
PSSP6	*Pseudoroegneria spicata*	bluebunch wheatgrass

Appendix H: Shrub Species Combinations.

Species Code	Latin Name	Common Name
ACGL	*Acer glabrum*	Rocky Mountain maple
ALINT	*Alnus incana* spp. *tenuifolia*	thinleaf alder
ALINT-BEOC2	*Alnus incana* spp. *tenuifolia-Betula occidentalis*	thinleaf alder-water birch
AMAL2	*Amelanchier alnifolia*	Saskatoon serviceberry
ARTR2	*Artemisia tridentata*	big sagebrush
ARTR2-CEMO2	*Artemisia tridentata-Cercocarpus montanus*	big sagebrush-alderleaf mountain mahogany
ARTR2-JUCO6	*Artemisia tridentata-Juniperus communis*	big sagebrush-common juniper
ARTRV	*Artemisia tridentata ssp. vaseyana*	mountain big sage
ARTRV-PUTR	*Artemisia tridentata ssp. vaseyana-Purshia tridentata*	mountain big sage-antelope bitterbrush
ARTRW8	*Artemisia tridentata ssp. wyomingensis*	Wyoming big sage
ARTRW8-CHVI8	*Artemisia tridentata ssp. wyomingensis-Chrysothamnus viscidiflorus*	Wyoming big sage-yellow rabbitbrush
ARTRW8-PUTR	*Artemisia tridentata ssp. wyomingensis-Purshia tridentata*	Wyoming big sage-antelope bitterbrush
ARUV	*Arctostaphylos uva-ursi*	kinnikinnick
CEMO2	*Cercocarpus montanus*	alderleaf mountain mahogany
CEMO2-ARTR2	*Cercocarpus montanus-Artemisia tridentata*	alderleaf mountain mahogany-big sagebrush
CEMO2-ARUV	*Cercocarpus montanus-Arctostaphylos uva-ursi*	alderleaf mountain mahogany-kinnikinnick
CEMO2-DAFL3	*Cercocarpus montanus-Dasiphora floribunda*	alderleaf mountain mahogany-shrubby cinquefoil
CEMO2-JUCO6	*Cercocarpus montanus-Juniperus communis*	alderleaf mountain mahogany-common juniper
CEMO2-PHMO4	*Cercocarpus montanus-Physocarpus monogynus*	alderleaf mountain mahogany-mountain ninebark
CEMO2-PUTR2	*Cercocarpus montanus-Purshia tridentata*	alderleaf mountain mahogany-antelope bitterbrush
CEMO2-QUGA	*Cercocarpus montanus-Quercus gambelii*	alderleaf mountain mahogany-Gambel oak
CEMO2-RIBES	*Cercocarpus montanus-Ribes* spp.	alderleaf mountain mahogany-current species
CEMO2-RICE	*Cercocarpus montanus-Ribes cereum*	alderleaf mountain mahogany-wax currant
CEMO2-SALIXU	*Cercocarpus montanus*-upland *Salix* spp.	alderleaf mountain mahogany-upland willow
CEMO2-SYOR2	*Cercocarpus montanus-Symphoricarpos oreophilus*	alderleaf mountain mahogany-mountain snowberry
CHIV	*Chrysothamnus viscidiflorus*	yellow rabbitbrush
DAFL3	*Dasiphora floribunda*	shrubby cinquefoil
ERPA	*Ericameria parryi*	Parry's rabbitbrush
JAAM	*Jamesia americana*	fivepetal cliffbrush
JUCO6	*Juniperus communis*	common juniper

Species Code	Latin Name	Common Name
JUCO6-ARUV	*Juniperus communis-Arctostaphylos uva-ursi*	common juniper-kinnikinnick
JUCO6-SALIXU	*Juniperus communis*-upland *Salix* spp.	common juniper-upland willow species
MESIC-SHRUB		Mesic Shrubs
PUTR	*Purshia tridentata*	antelope bitterbrush
PUTR-ARTR	*Purshia tridentata-Artemisia tridentata*	antelope bitterbrush-big sagebrush
PUTR-CEMO2	*Purshia tridentata-Cercocarpus montanus*	antelope bitterbrush-alderleaf mountain mahogany
PUTR-RIBES	*Purshia tridentata-Ribes* spp.	antelope bitterbrush-currant species
QUGA	*Quercus gambelii*	Gambel oak
QUGA-AMAL2	*Quercus gambelii-Amelanchier alnifolia*	Gambel oak-Saskatoon serviceberry
QUGA-ARUV	*Quercus gambelii-Arctostaphylos uva-ursi*	Gambel oak-kinnikinnick
QUGA-CEMO2	*Quercus gambelii-Cercocarpus montanus*	Gambel oak-alderleaf mountain mahogany
QUGA-JUCO6	*Quercus gambelii-Juniperus communis*	Gambel oak-common juniper
QUGA-SALIXU	*Quercus gambelii*-upland *Salix* spp.	Gambel oak-upland willow species
QUGA-VASC	*Quercus gambelii-Vaccinium scoparium*	Gambel oak-grouse whortleberry
RIBES	*Ribes* spp.	currant species
RIBES-PUTR	*Ribes* spp.-*Purshia tridentata*	currant species- antelope bitterbrush
RICE	*Ribes cereum*	wax currant
SAGL	*Salix glauca*	grayleaf willow
SALIX	*Salix* spp.	riparian willow species
SALIX-ALIN	*Salix* spp.-*Alnus incana* spp. *tenuifolia*	riparian willow spp.-thinleaf alder
SALIX-BEOC2	*Salix* spp.-*Betula occidentalis*	riparian willow spp.-water birch
SALIXU	upland *Salix* spp.	upland willow species
SALIXU-RIBES	upland *Salix* spp.-*Ribes* spp.	upland willow spp.-currant spp.
SHCA	*Shepherdia canadensis*	russet buffaloberry
VAMY2	*Vaccinium myrtillus*	whortleberry
VASC	*Vaccinium scoparium*	grouse whortleberry
XERIC-SHRUB		Xeric Shrubs

Appendix I: Woodland Species Combinations.

Species Code	Latin Name	Common Name
JUMO	*Juniperus monosperma*	oneseed juniper
JUMO-PIED	*Juniperus monosperma-Pinus edulis*	oneseed juniper-two-needle pinyon
JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper
JUSC2-PIED	*Juniperus scopulorum-Pinus edulis*	Rocky Mountain juniper-two-needle pinyon
PIED	*Pinus edulis*	two-needle pinyon
PIED-JUMO	*Pinus edulis-Juniperus monosperma*	two-needle pinyon-oneseed juniper
PIED-JUSC2	*Pinus edulis-Juniperus scopulorum*	two-needle pinyon-Rocky Mountain juniper

Appendix J: Forest Species Combinations.

Species Code	Latin Name	Common Name
ABCO	*Abies concolor*	white fir
ABCO-PIEN	*Abies concolor-Picea engelmannii*	white fir-Engelmann spruce
ABCO-PIFL2	*Abies concolor-Pinus flexilis*	white fir-limber pine
ABCO-PIPO	*Abies concolor-Pinus ponderosa*	white fir-ponderosa pine
ABCO-POTR5	*Abies concolor-Populus tremuloides*	white fir-quaking aspen
ABCO-PSME	*Abies concolor-Pseudotsuga menziesii*	white fir-Douglas-fir
ABLA	*Abies lasiocarpa*	subalpine fir
ABLA-PIAR	*Abies lasiocarpa-Pinus aristata*	subalpine fir-bristlecone pine
ABLA-PICO	*Abies lasiocarpa-Pinus contorta*	subalpine fir-lodgepole pine
ABLA-PIEN	*Abies lasiocarpa-Picea engelmannii*	subalpine fir-Engelmann spruce
ABLA-PIFL2	*Abies lasiocarpa-Pinus flexilis*	subalpine fir-limber pine
ACNE2	*Acer negundo*	boxelder
ACNE2-PSME	*Acer negundo-Pseudotsuga menziesii*	boxelder-Douglas-fir
JUSC2-PIPO	*Juniperus scopulorum-Pinus ponderosa*	Rocky Mountain juniper-ponderosa pine
JUSC2-POTR5	*Juniperus scopulorum-Populus tremuloides*	Rocky Mountain juniper-quaking aspen
JUSC2-PSME	*Juniperus scopulorum-Pseudotsuga menziesii*	Rocky Mountain juniper-Douglas-fir
PIAR	*Pinus aristata*	bristlecone pine
PIAR-PICO	*Pinus aristata-Pinus contorta*	bristlecone pine-lodgepole pine
PIAR-PIEN	*Pinus aristata-Picea engelmannii*	bristlecone pine-Engelmann spruce
PIAR-PIFL2	*Pinus aristata-Pinus flexilis*	bristlecone pine-limber pine
PIAR-PIPO	*Pinus aristata-Pinus ponderosa*	bristlecone pine-ponderosa pine
PIAR-POTR5	*Pinus aristata-Populus tremuloides*	bristlecone pine-quaking aspen
PIAR-PSME	*Pinus aristata-Pseudotsuga menziesii*	bristlecone pine-Douglas-fir
PICO	*Pinus contorta*	lodgepole pine
PICO-ABLA	*Pinus contorta-Abies lasiocarpa*	lodgepole pine-subalpine fir
PICO-PIEN	*Pinus contorta-Picea engelmannii*	lodgepole pine-Engelmann spruce
PICO-PIFL2	*Pinus contorta-Pinus flexilis*	lodgepole pine-limber pine
PICO-PIPO	*Pinus contorta-Pinus ponderosa*	lodgepole pine-ponderosa pine
PICO-POTR5	*Pinus contorta-Populus tremuloides*	lodgepole pine-quaking aspen
PICO-PSME	*Pinus contorta-Pseudotsuga menziesii*	lodgepole pine-Douglas-fir
PIED-ABCO	*Pinus edulis-Abies concolor*	two-needle pinyon-white fir
PIED-PIAR	*Pinus edulis-Pinus aristata*	two-needle pinyon-bristlecone pine
PIED-PIPO	*Pinus edulis-Pinus ponderosa*	two-needle pinyon-ponderosa pine
PIED-POTR5	*Pinus edulis-Populus tremuloides*	two-needle pinyon-quaking aspen
PIED-PSME	*Pinus edulis-Pseudotsuga menziesii*	two-needle pinyon-Douglas-fir

Species Code	Latin Name	Common Name
PIEN	*Picea engelmannii*	Engelmann spruce
PIEN-ABCO	*Picea engelmannii-Abies concolor*	Engelmann spruce-white fir
PIEN-ABLA	*Picea engelmannii-Abies lasiocarpa*	Engelmann spruce-subalpine fir
PIEN-PIAR	*Picea engelmannii-Pinus aristata*	Engelmann spruce-bristlecone pine
PIEN-PICO	*Picea engelmannii-Pinus contorta*	Engelmann spruce-lodgepole pine
PIEN-PIFL2	*Picea engelmannii-Pinus flexilis*	Engelmann spruce-limber pine
PIEN-PIPU	*Picea engelmannii-Picea pungens*	Engelmann spruce-blue spruce
PIEN-POTR5	*Picea engelmannii-Populus tremuloides*	Engelmann spruce-quaking aspen
PIEN-PSME	*Picea engelmannii-Pseudotsuga menziesii*	Engelmann spruce-Douglas-fir
PIFL2	Pinus flexilis	limber pine
PIFL2-ABCO	Pinus flexilis-Abies concolor	limber pine-white fir
PIFL2-PIAR	*Pinus flexilis-Pinus aristata*	limber pine-bristlecone pine
PIFL2-PICO	*Pinus flexilis-Pinus contorta*	limber pine-lodgepole pine
PIFL2-PIEN	*Pinus flexilis-Picea engelmannii*	limber pine-Engelmann spruce
PIFL2-PIPO	*Pinus flexilis-Pinus ponderosa*	limber pine-ponderosa pine
PIFL2-POTR5	*Pinus flexilis-Populus tremuloides*	limber pine-quaking aspen
PIFL2-PSME	*Pinus flexilis-Pseudotsuga menziesii*	limber pine-Douglas-fir
PIPO	*Pinus ponderosa*	ponderosa pine
PIPO-ABCO	*Pinus ponderosa-Abies concolor*	ponderosa pine-white fir
PIPO-JUSC2	*Pinus ponderosa-Juniperus scopulorum*	ponderosa pine-Rocky Mountain juniper
PIPO-PIAR	*Pinus ponderosa-Pinus aristata*	ponderosa pine-bristlecone pine
PIPO-PICO	*Pinus ponderosa-Pinus contorta*	ponderosa pine-lodgepole pine
PIPO-PIED	*Pinus ponderosa-Pinus edulis*	ponderosa pine-two-needle pinyon
PIPO-PIFL2	*Pinus ponderosa-Pinus flexilis*	ponderosa pine-limber pine
PIPO-PIPU	*Pinus ponderosa-Picea pungens*	ponderosa pine-blue spruce
PIPO-POAN3	*Pinus ponderosa-Populus angustifolia*	ponderosa pine-narrowleaf cottonwood
PIPO-POTR5	*Pinus ponderosa-Populus tremuloides*	ponderosa pine-quaking aspen
PIPO-PSME	*Pinus ponderosa-Pseudotsuga menziesii*	ponderosa pine-Douglas-fir
PIPU	*Picea pungens*	blue spruce
PIPU-PIPO	*Picea pungens-Pinus ponderosa*	blue spruce-ponderosa pine
PIPU-POAN3	*Picea pungens-Populus angustifolia*	blue spruce-narrowleaf cottonwood
PIPU-POTR5	*Picea pungens-Populus tremuloides*	blue spruce-quaking aspen
PIPU-PSME	*Picea pungens-Pseudotsuga menziesii*	blue spruce-Douglas-fir
POAN3	*Populus angustifolia*	narrowleaf cottonwood
POAN3-PIPO	*Populus angustifolia-Pinus ponderosa*	narrowleaf cottonwood-ponderosa pine

Species Code	Latin Name	Common Name
POAN3-PIPU	*Populus angustifolia-Picea pungens*	narrowleaf cottonwood-blue spruce
POAN3-POTR5	*Populus angustifolia-Populus tremuloides*	narrowleaf cottonwood-quaking aspen
POAN3-PSME	*Populus angustifolia-Pseudotsuga menziesii*	narrowleaf cottonwood-Douglas-fir
POTR5	*Populus tremuloides*	quaking aspen
POTR5-ABCO	*Populus tremuloides-Abies concolor*	quaking aspen-white fir
POTR5-ABLA	*Populus tremuloides-Abies lasiocarpa*	quaking aspen-subalpine fir
POTR5-PIAR	*Populus tremuloides-Pinus aristata*	quaking aspen-bristlecone pine
POTR5-PICO	*Populus tremuloides-Pinus contorta*	quaking aspen-lodgepole pine
POTR5-PIEN	*Populus tremuloides-Picea engelmannii*	quaking aspen-Engelmann spruce
POTR5-PIFL2	*Populus tremuloides-Pinus flexilis*	quaking aspen-limber pine
POTR5-PIPO	*Populus tremuloides-Pinus ponderosa*	quaking aspen-ponderosa pine
POTR5-PIPU	*Populus tremuloides-Picea pungens*	quaking aspen-blue spruce
POTR5-POAN3	*Populus tremuloides-Populus angustifolia*	quaking aspen-narrowleaf cottonwood
POTR5-PSME	*Populus tremuloides-Pseudotsuga menziesii*	quaking aspen-Douglas-fir
PSME	*Pseudotsuga menziesii*	Douglas-fir
PSME-ABCO	*Pseudotsuga menziesii-Abies concolor*	Douglas-fir-white fir
PSME-JUSC2	*Pseudotsuga menziesii-Juniperus scopulorum*	Douglas-fir-Rocky Mountain juniper
PSME-PIAR	*Pseudotsuga menziesii-Pinus aristata*	Douglas-fir-bristlecone pine
PSME-PICO	*Pseudotsuga menziesii-Pinus contorta*	Douglas-fir-lodgepole pine
PSME-PIED	*Pseudotsuga menziesii-Pinus edulis*	Douglas-fir-two-needle pinyon
PSME-PIEN	*Pseudotsuga menziesii-Picea engelmannii*	Douglas-fir-Engelmann spruce
PSME-PIFL2	*Pseudotsuga menziesii-Pinus flexilis*	Douglas-fir-limber pine
PSME-PIPO	*Pseudotsuga menziesii-Pinus ponderosa*	Douglas-fir-ponderosa pine
PSME-PIPU	*Pseudotsuga menziesii-Picea pungens*	Douglas-fir-blue spruce
PSME-POTR5	*Pseudotsuga menziesii-Populus tremuloides*	Douglas-fir-quaking aspen

Appendix K: Graminoid Species Combinations Based on Literature Review.

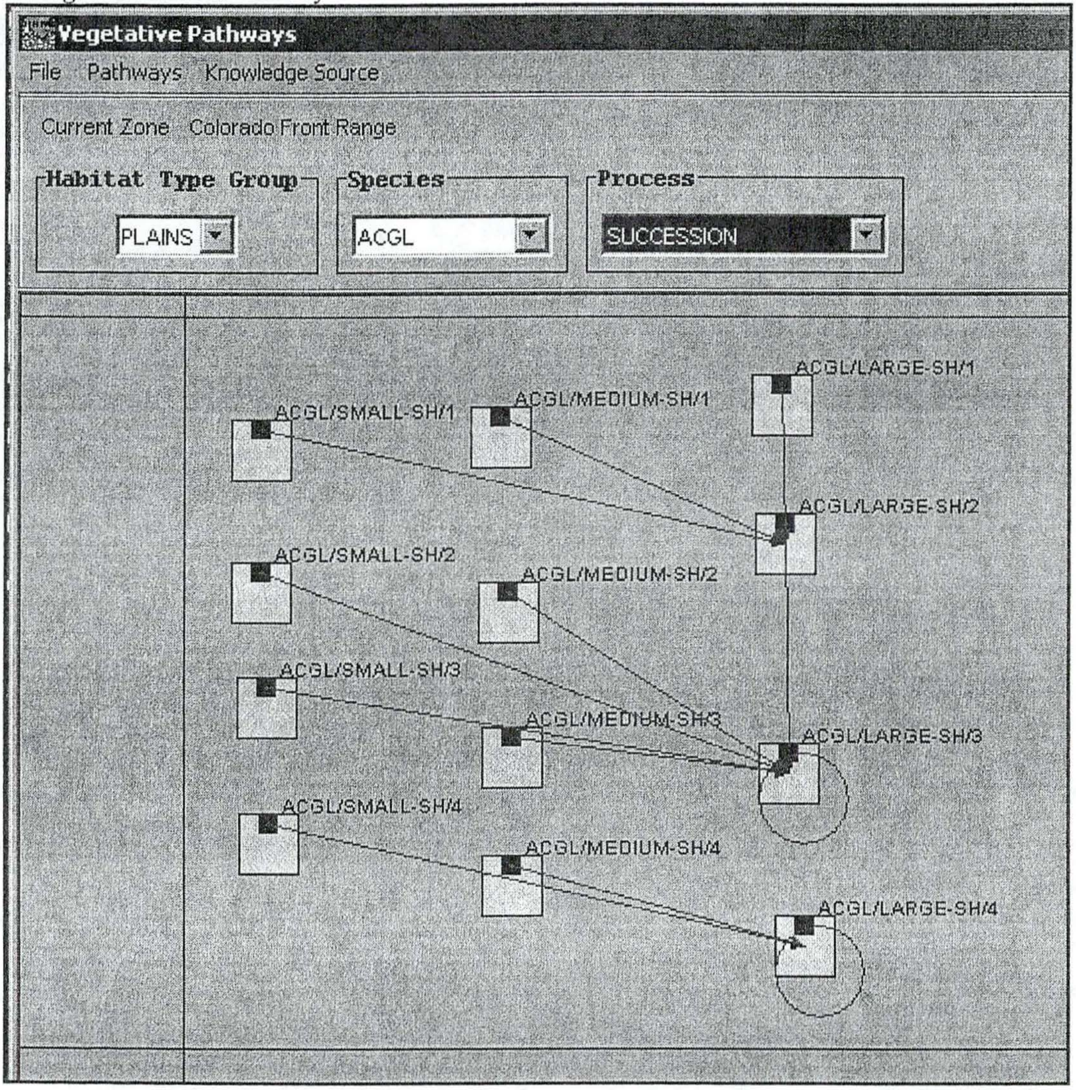
SIMPPLLE Code	Scientific Name
ACHY	*Achnatherum hymenoides*
AG-FORBS	Annual grass-Forbs
BOGR2	*Bouteloua gracilis*
BRTE	*Bromus tectorum*
CACA4	*Calamagrostis canadensis*
CAFO3	*Carex foenea*
CAPU	*Calamagrostis purpurascens*
CAREXU	upland *Carex* species
CAREXU-CARU	upland *Carex* species-*Calamagrostis rubescens*
FEAR2	*Festuca arizonica*
FEAR2-BOGR2	*Festuca arizonica-Bouteloua gracilis*
FEAR2-DAPA2	*Festuca arizonica-Danthonia parryi*
FEAR2-MUMO	*Festuca arizonica-Muhlenbergia montana*
FEID	*Festuca idahoensis*
FETH	*Festuca thurberi*
PASM	*Pascopyrum smithii*
PG-FORBS	Perennial grass-Forbs
POFE	*Poa fendleriana*
POPR	*Poa pratensis*
PSSP6	*Pseudoroegneria spicata*

Appendix L: Shrub Species Combinations Based on Literature Review.

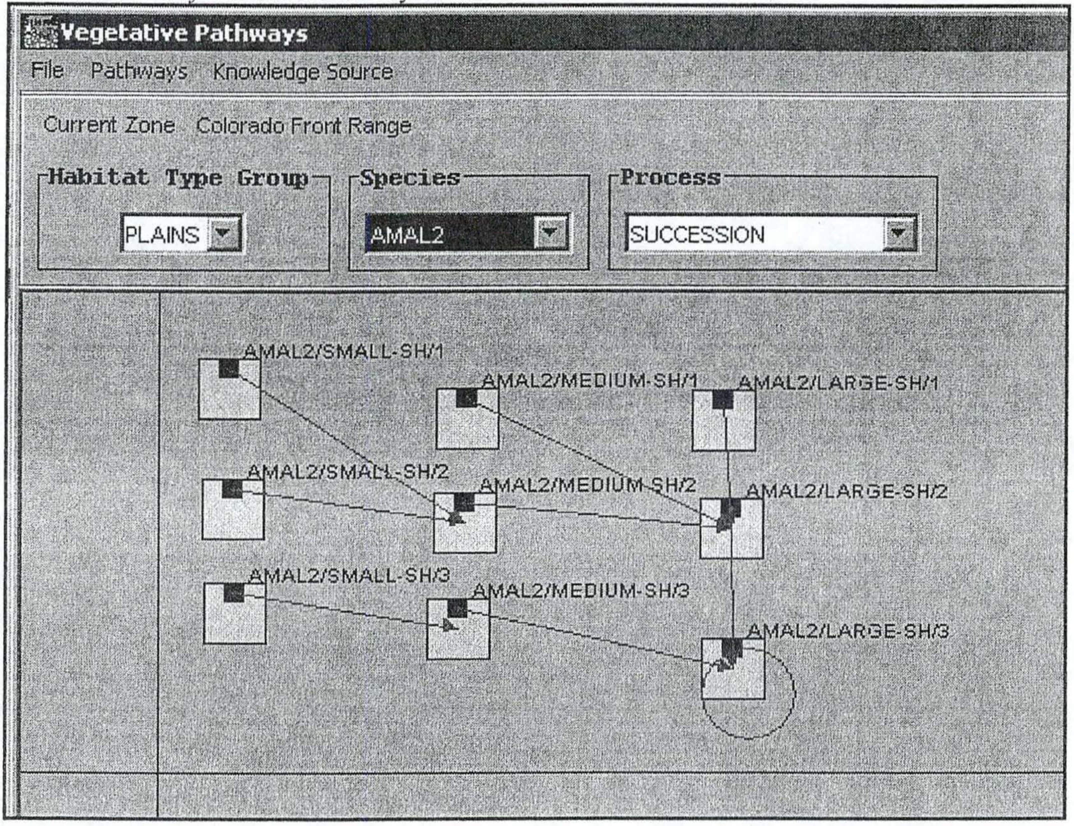
SIMPPLLE Code	Scientific Name
ALINT-BEOC2	*Alnus incana* spp. *tenuifolia-Betula occidentalis*
AMAL2	*Amelanchier alnifolia*
ARTRV	*Artemisia tridentata* ssp. *vaseyana*
ARTRV-PUTR	*Artemisia tridentata* ssp. *vaseyana-Purshia tridentata*
ARTRW8	*Artemisia tridentata* ssp. *wyomingensis*
ARTRW8-CHVI8	*Artemisia tridentata* ssp. *wyomingensis-Chrysothamnus viscidiflorus*
CHVI8	*Chrysothamnus viscidiflorus*
ERPAA4	*Ericameria parryi*
PHMO	*Physocarpus monogynus*
QUGA-AMAL2	*Quercus gambelii-Amelanchier alnifolia*
RIBES-PUTR2	*Ribes* spp.-*Purshia tridentata*
SALIXU	upland *Salix* spp.

Appendix M: Unique Shrub and Woodland Pathways for the Colorado Front Range Version of SIMPPLLE

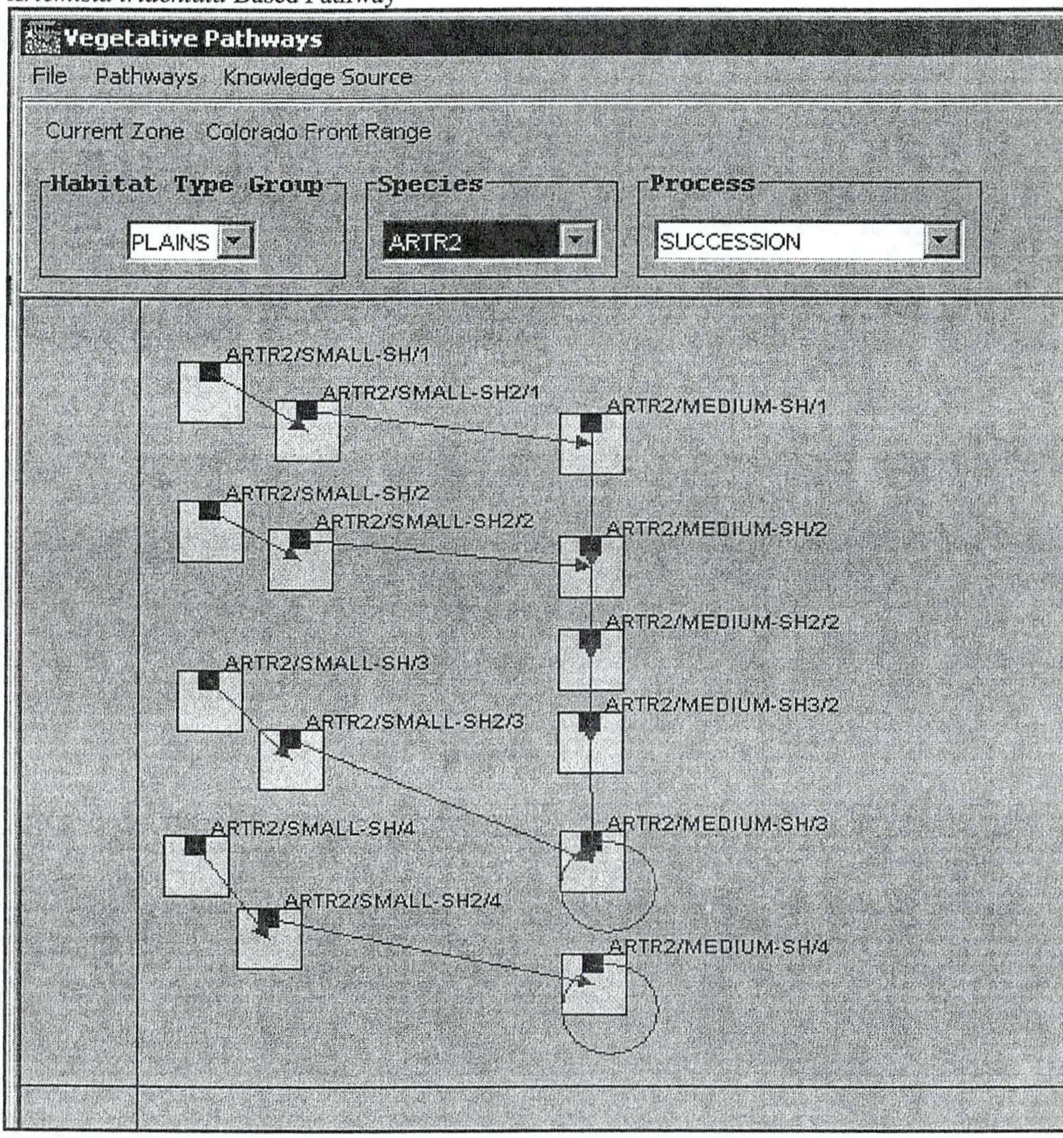
Acer glabrum Based Pathway



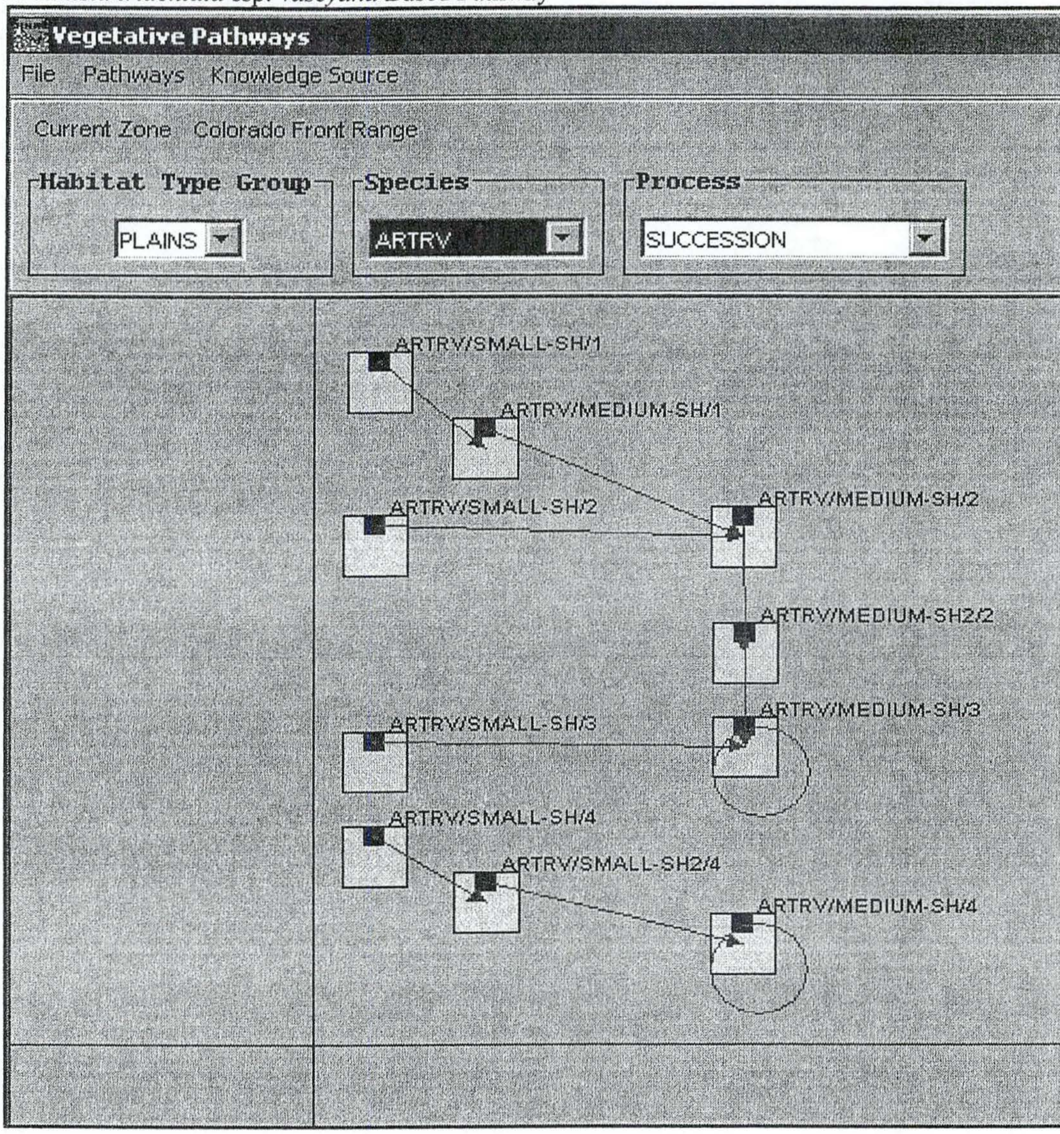
Amelanchier alnifolia Based Pathway



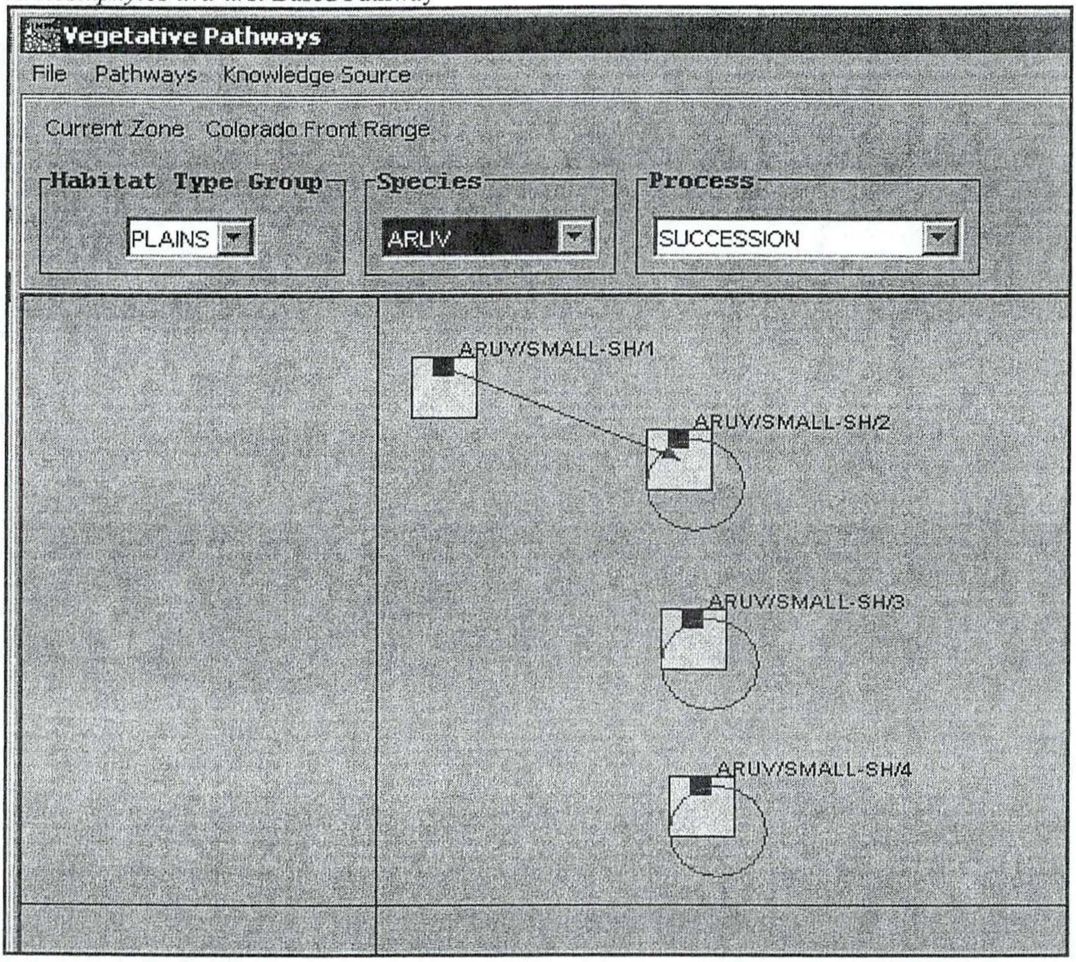
Artemisia tridentata Based Pathway



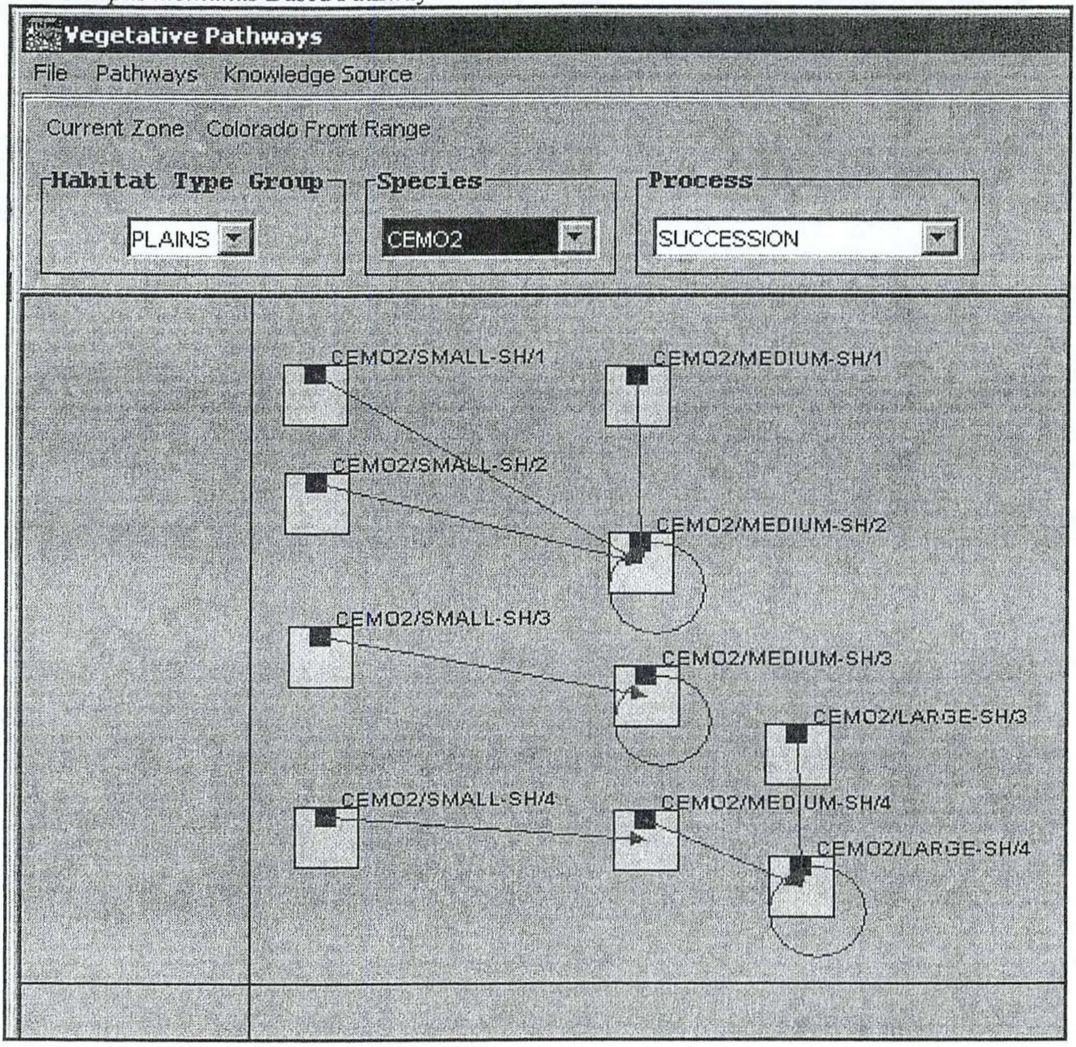
Artemisia tridentata ssp. *vaseyana* Based Pathway



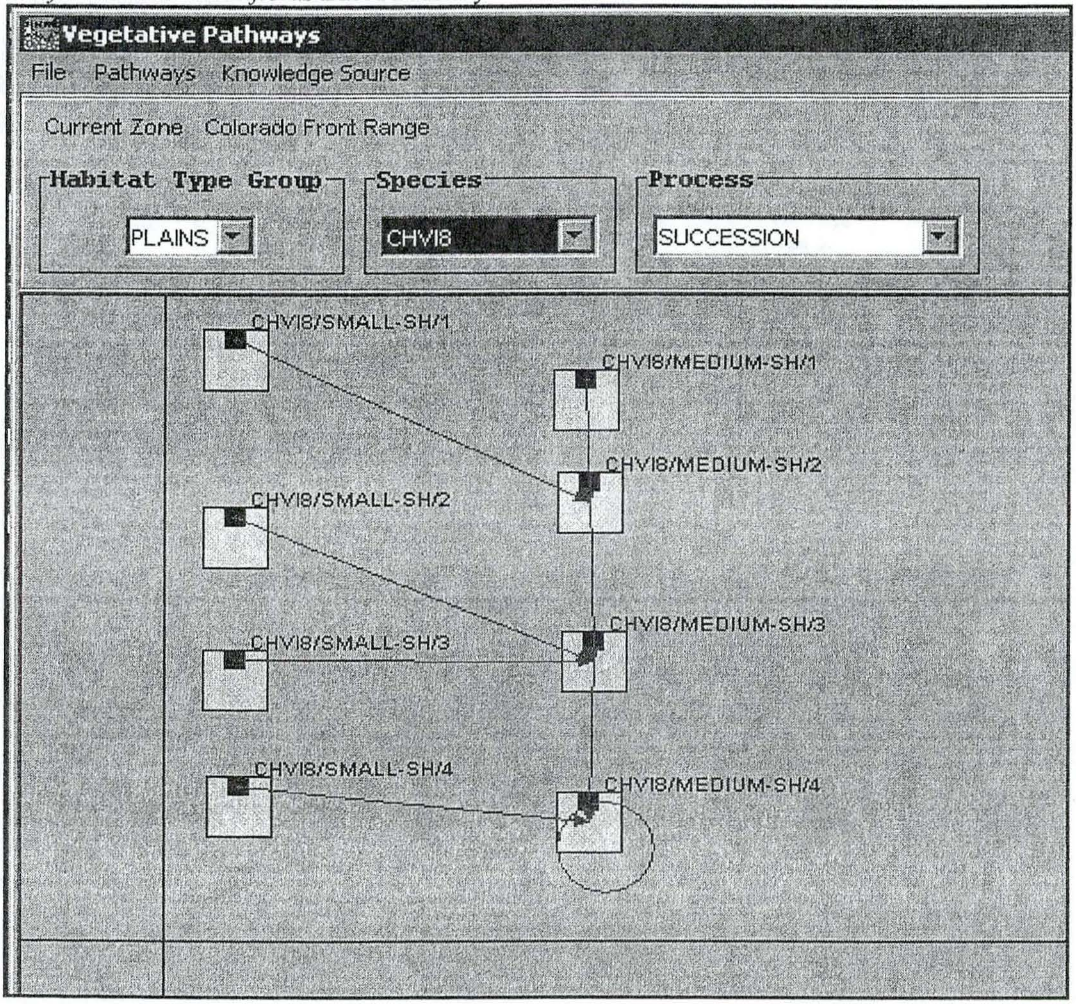
Arctostaphylos uva-ursi Based Pathway



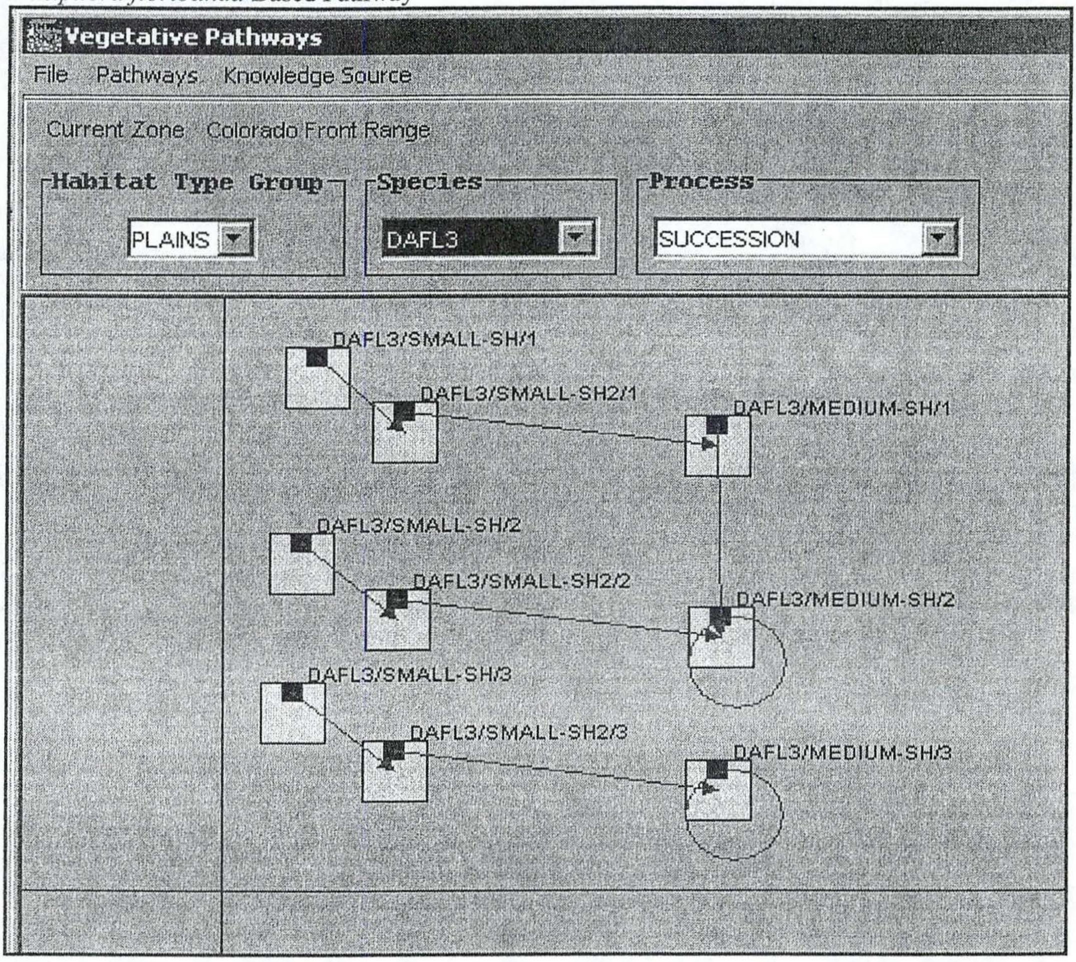
Cercocarpus montanus Based Pathway



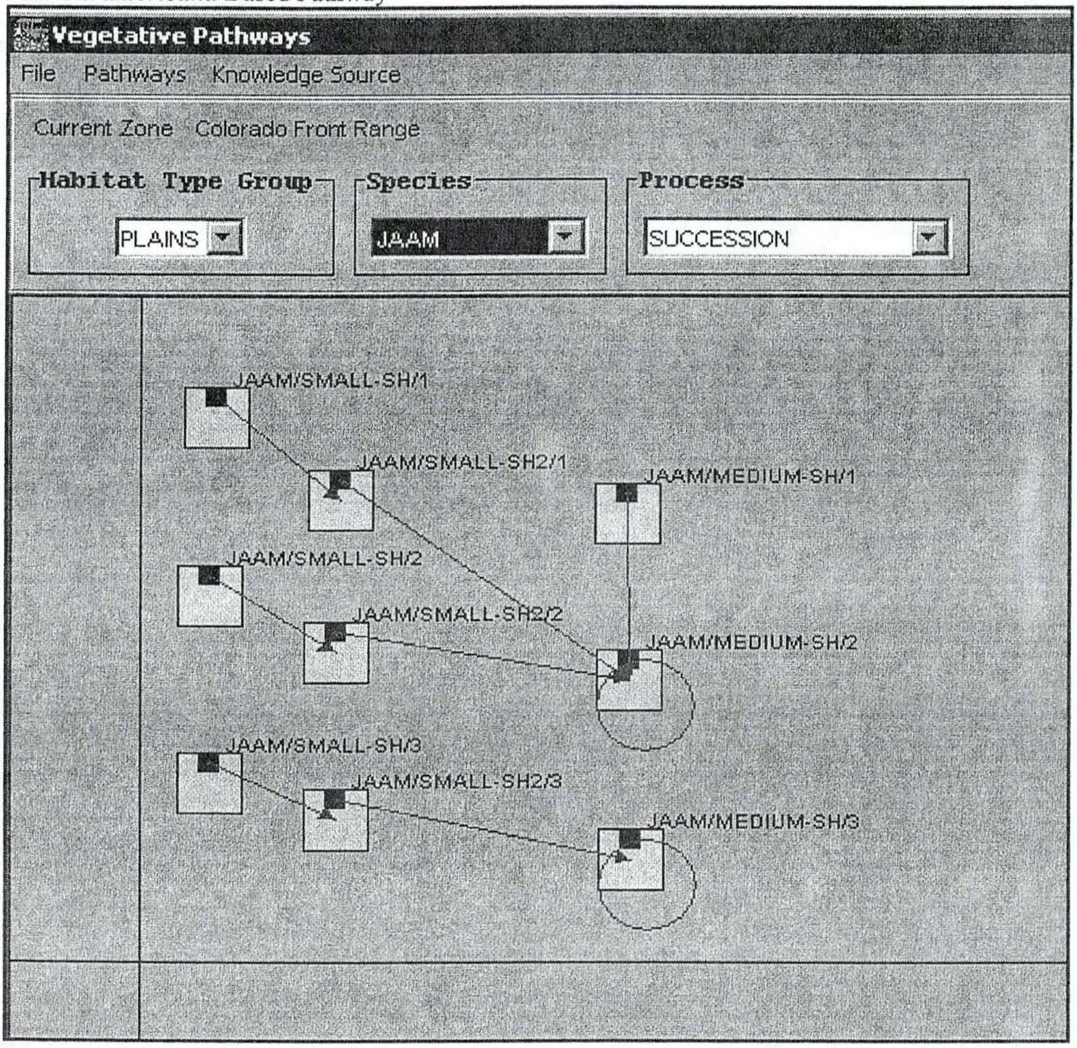
Chrysothamnus viscidiflorus Based Pathway



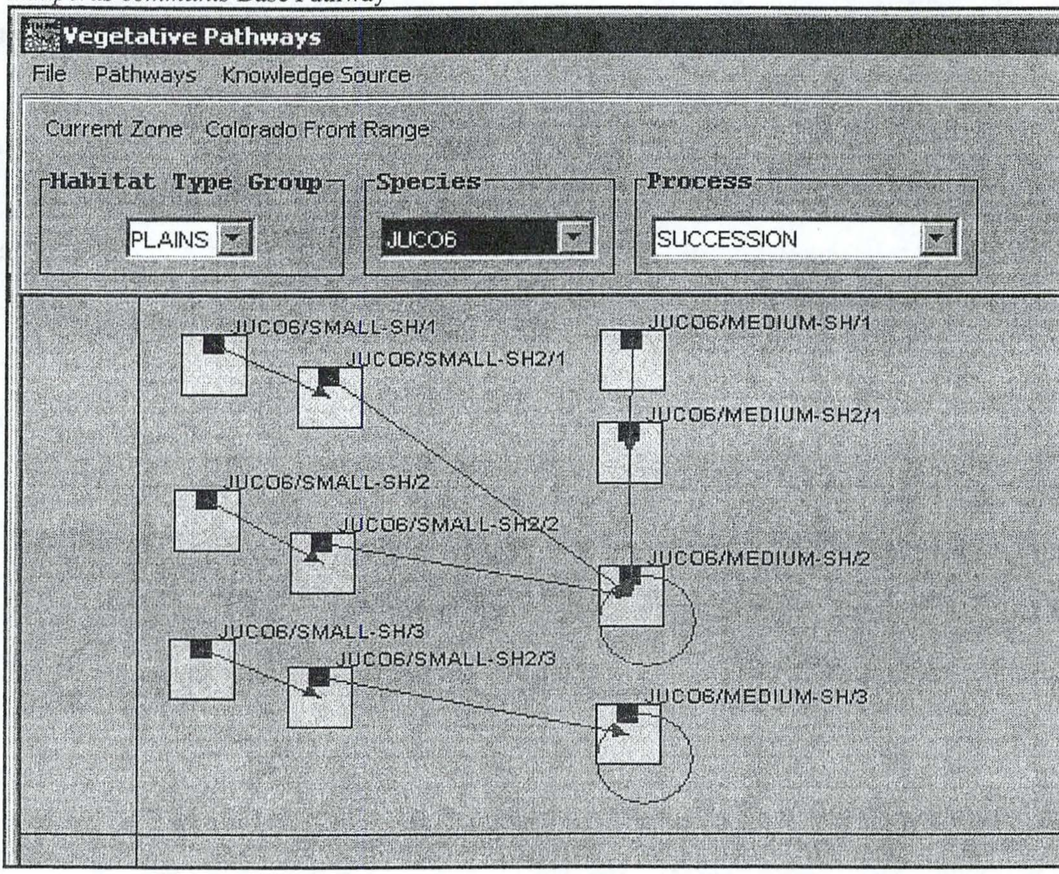
Dasiphora floribunda Based Pathway



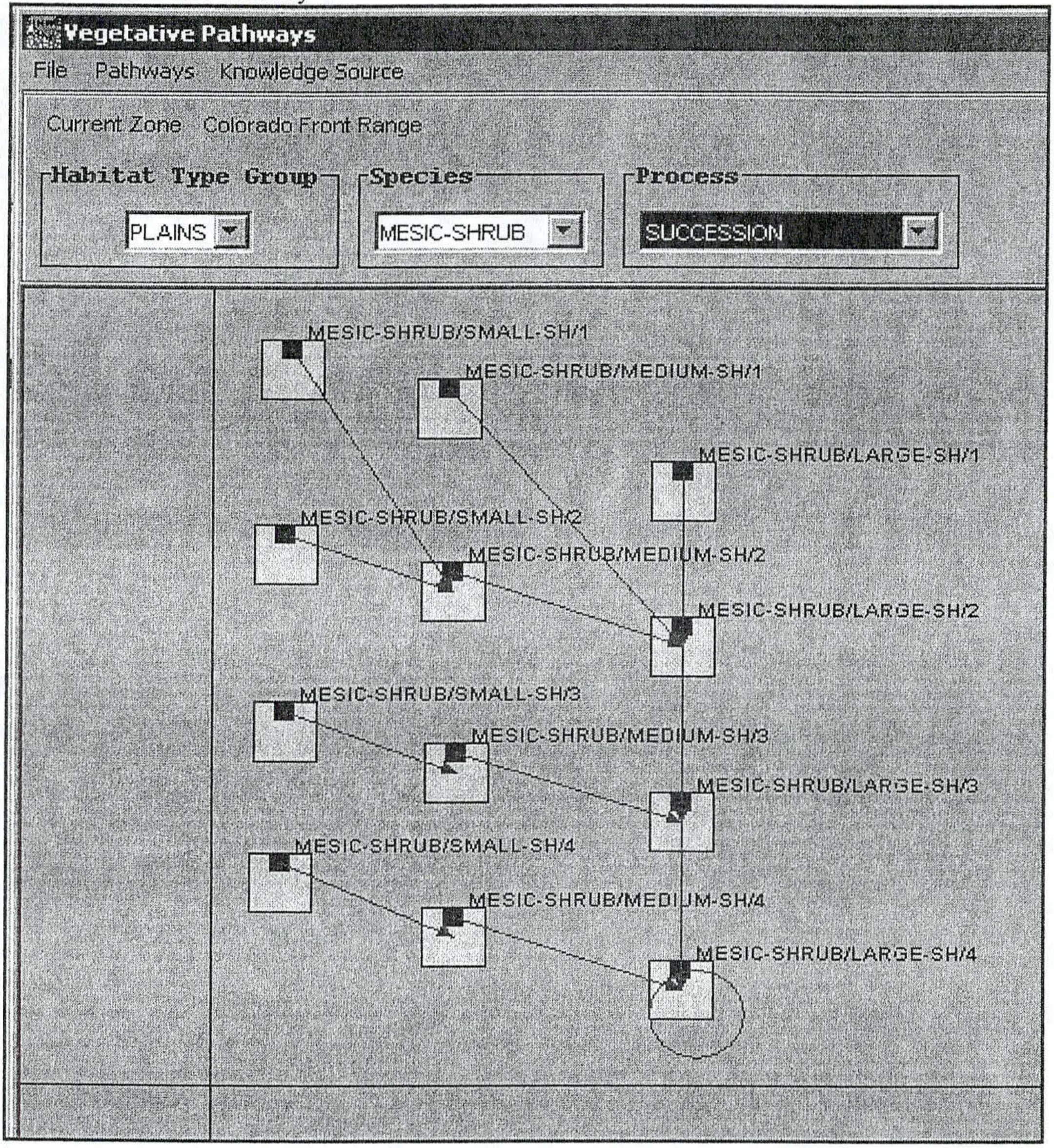
Jamesia americana Based Pathway



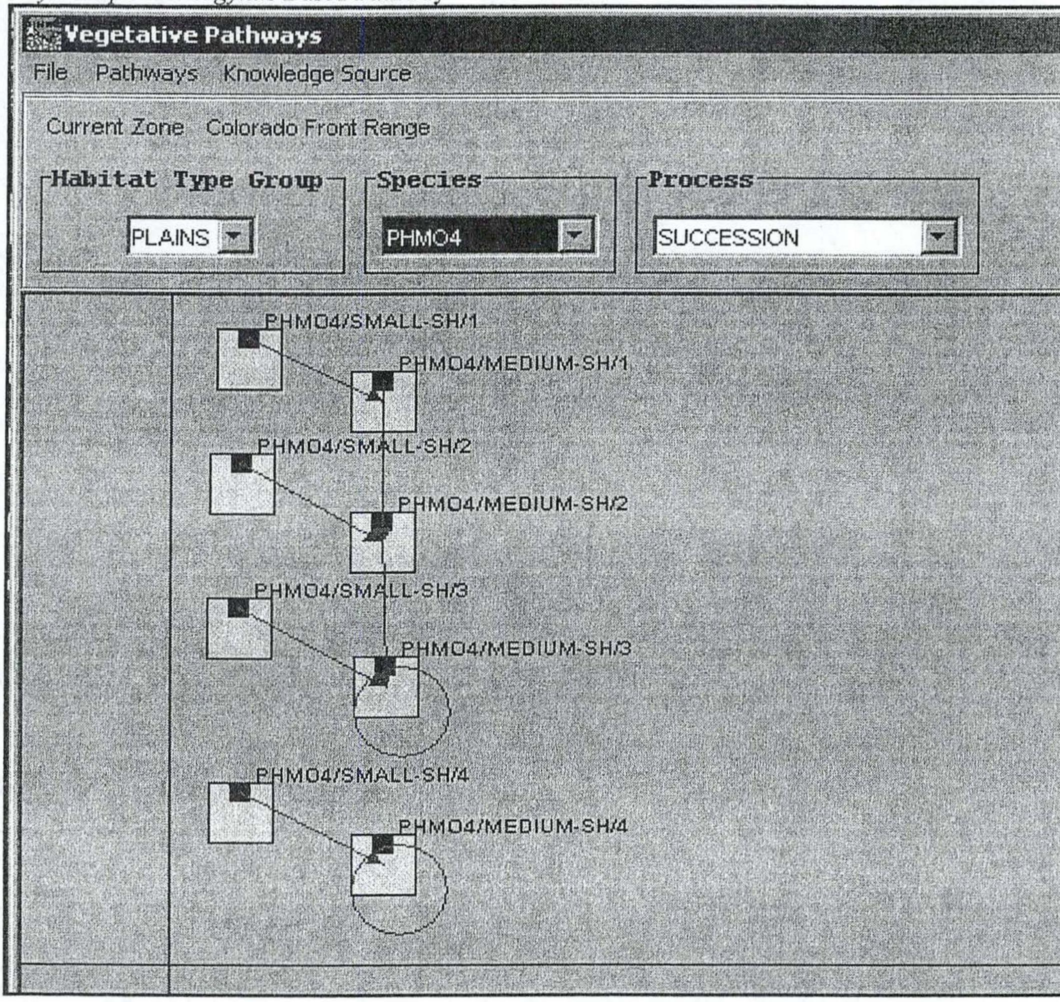
Juniperus communis Base Pathway



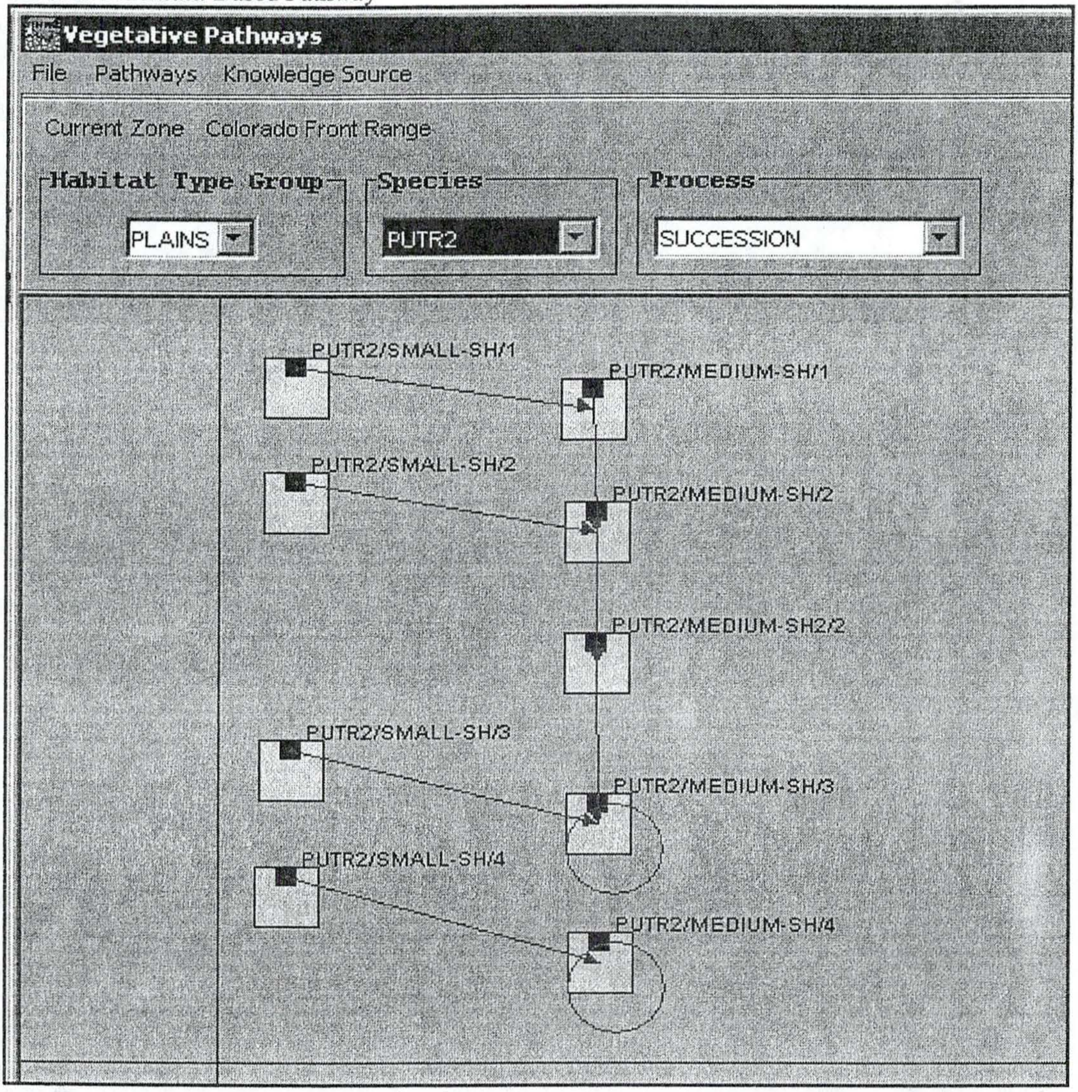
Mesic Shrub Based Pathway



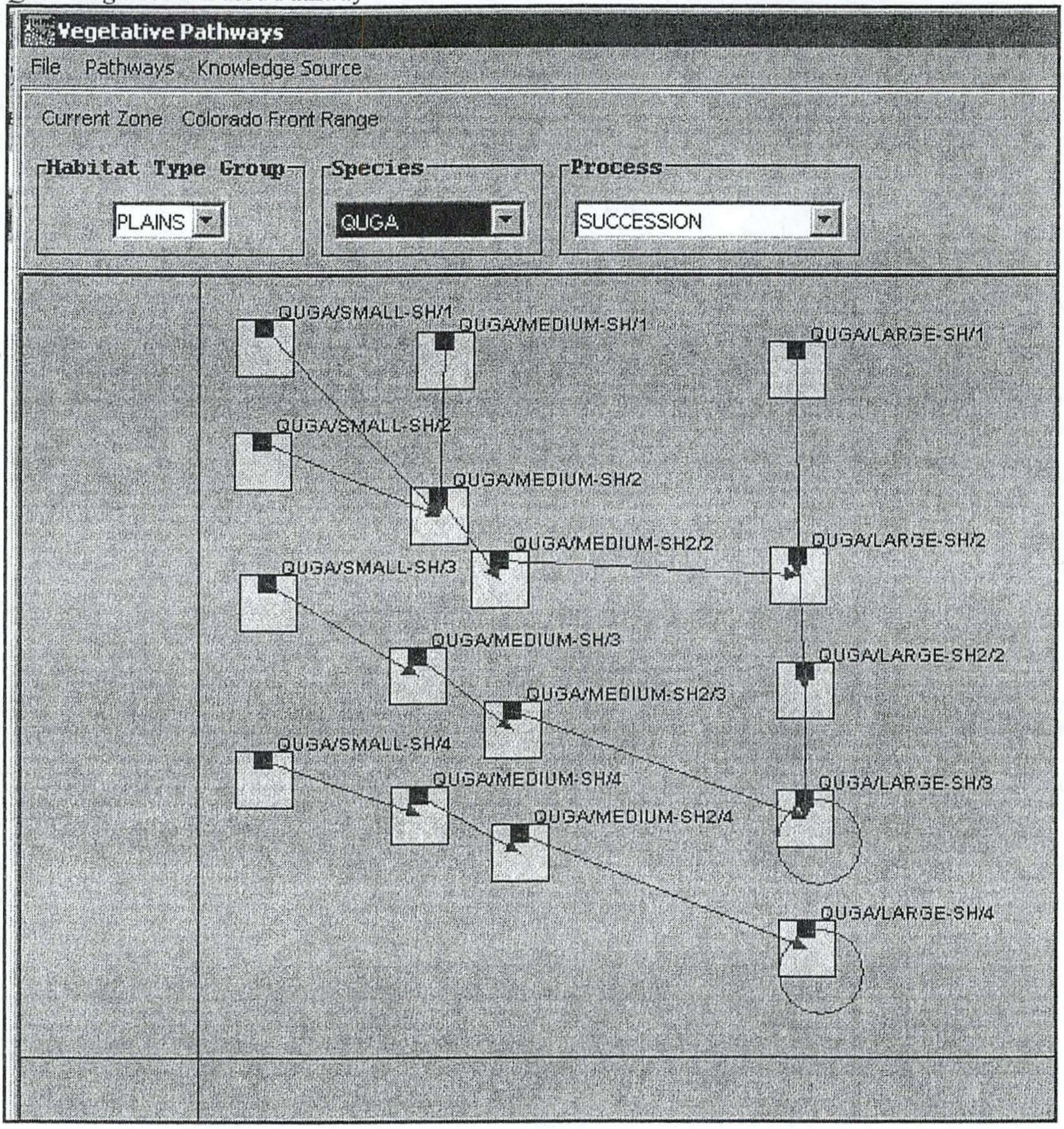
Physocarpus monogynus Based Pathway



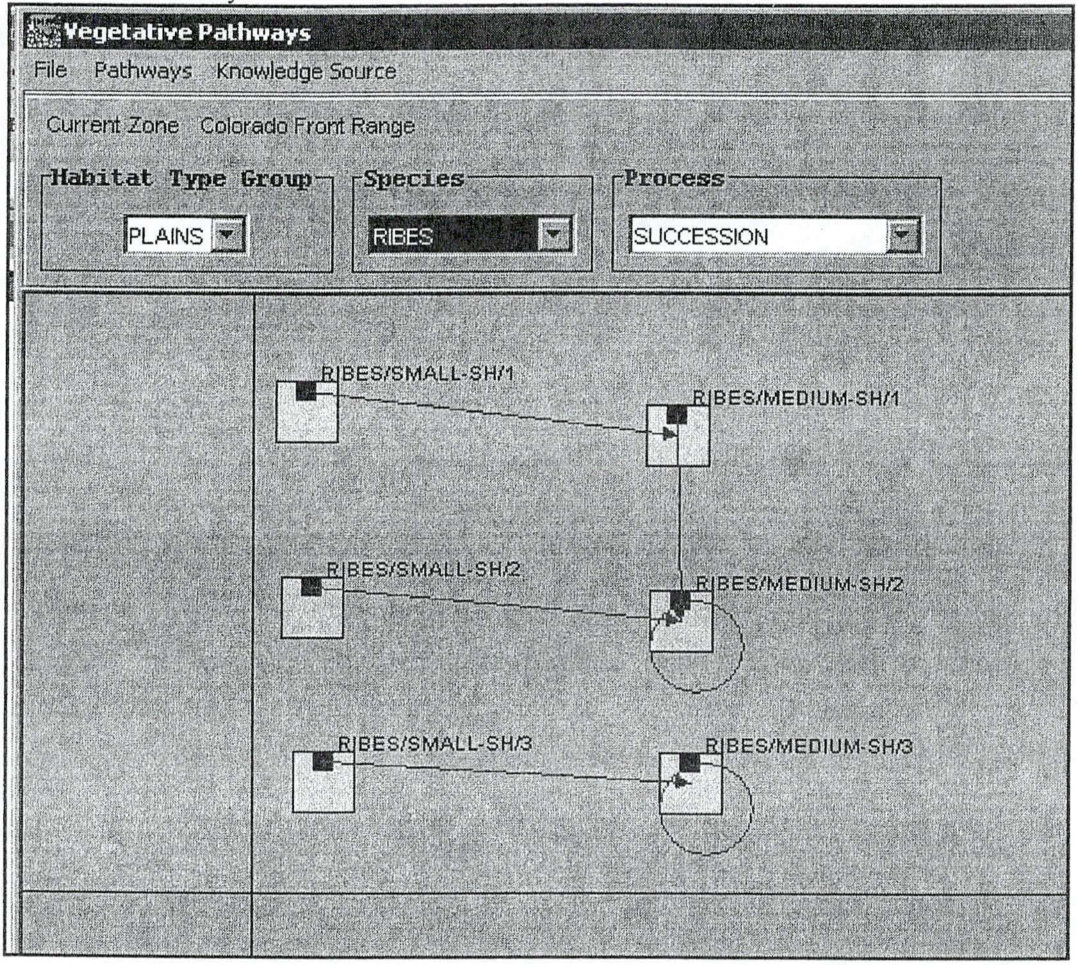
Purshia tridentata Based Pathway



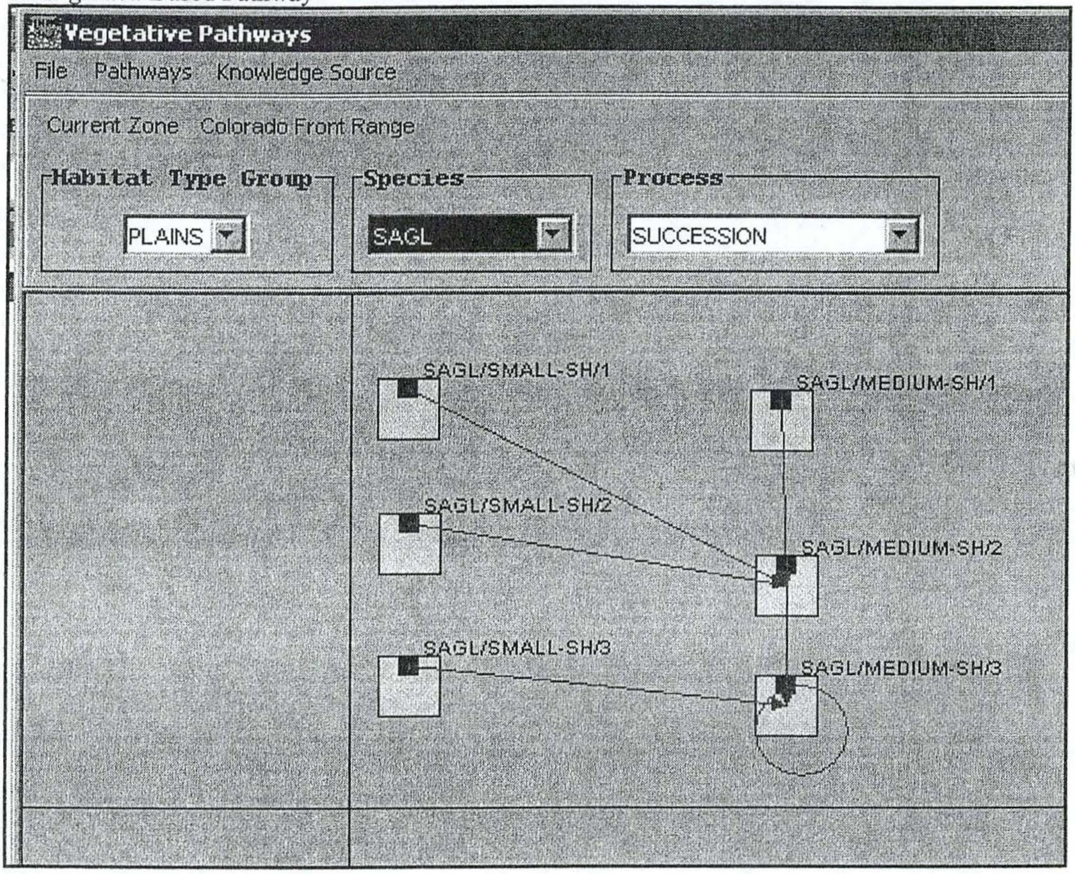
Quercus gambelii Based Pathway



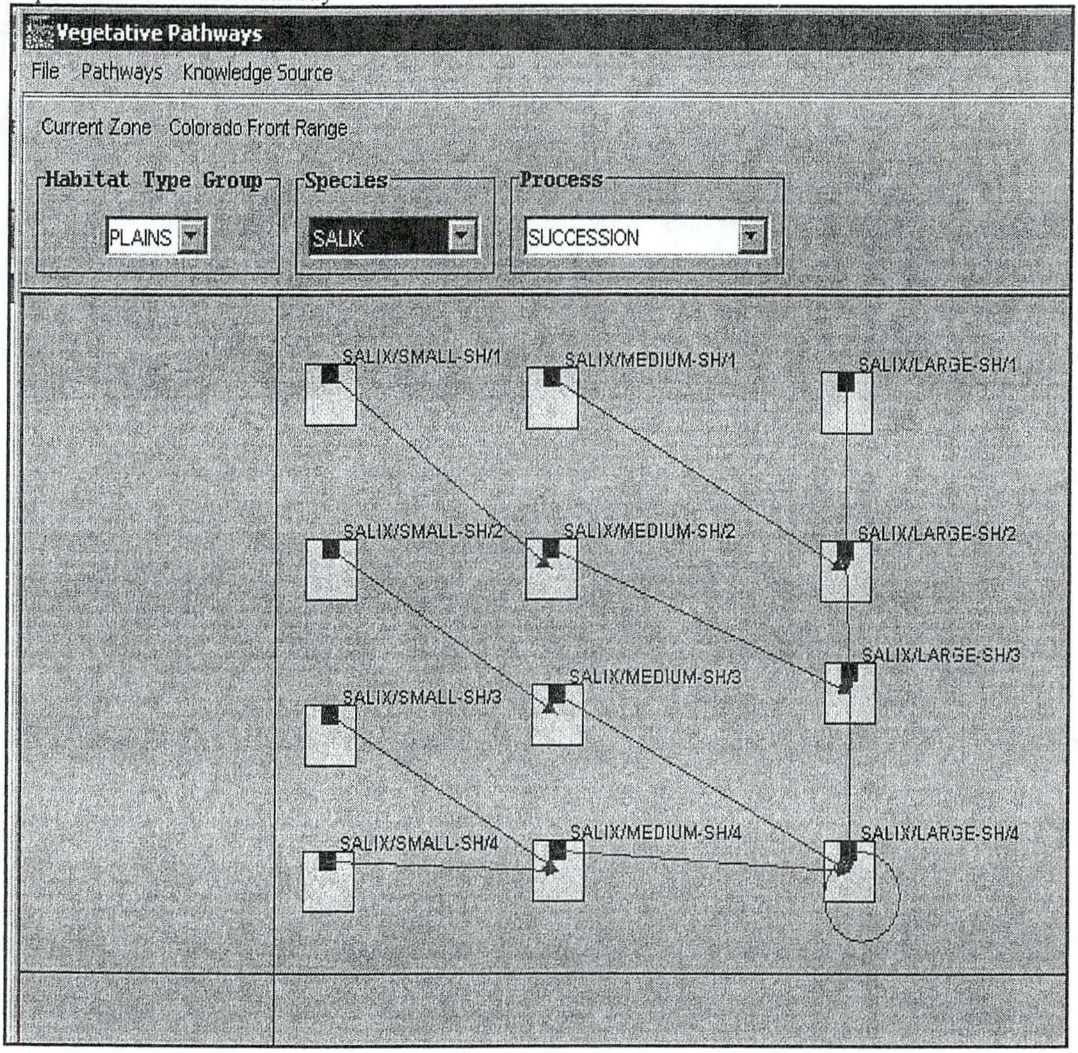
Ribes Based Pathway



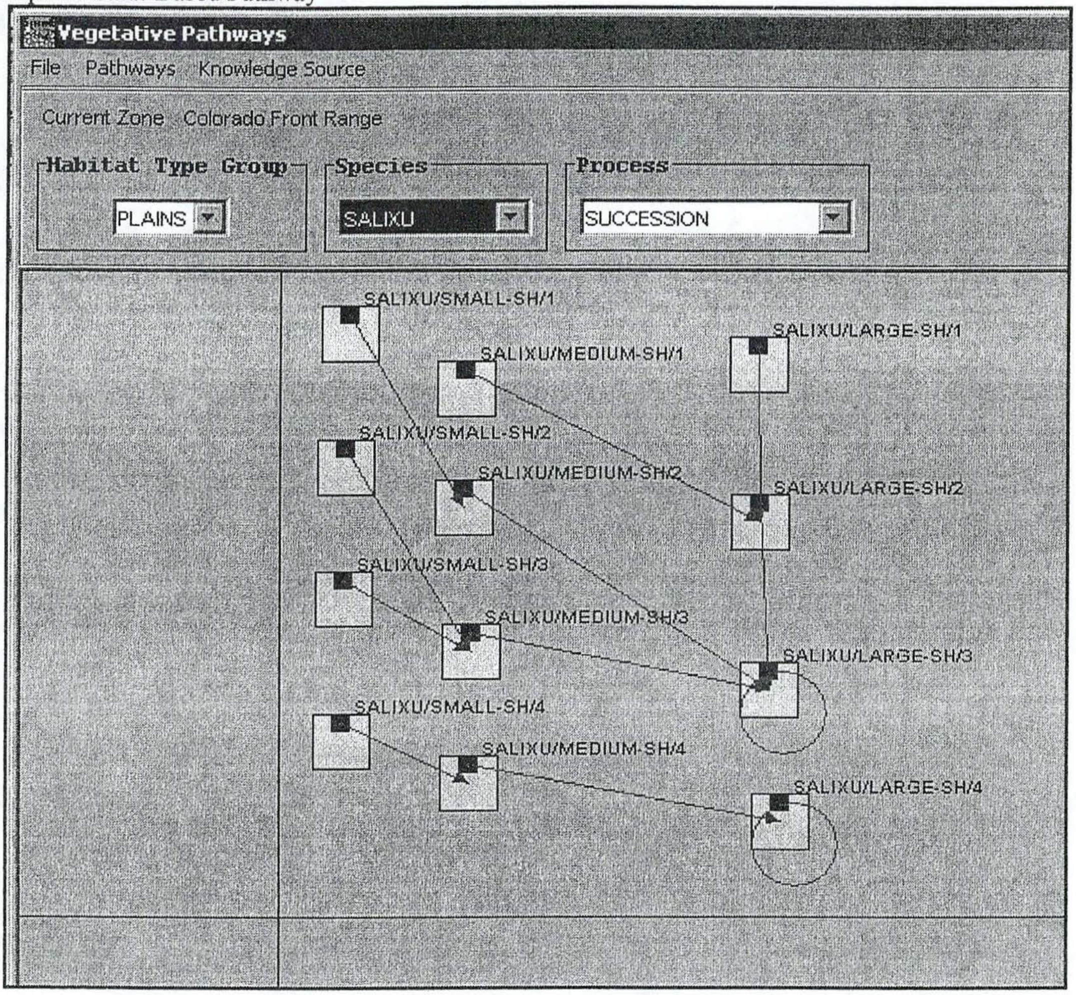
Salix glauca Based Pathway



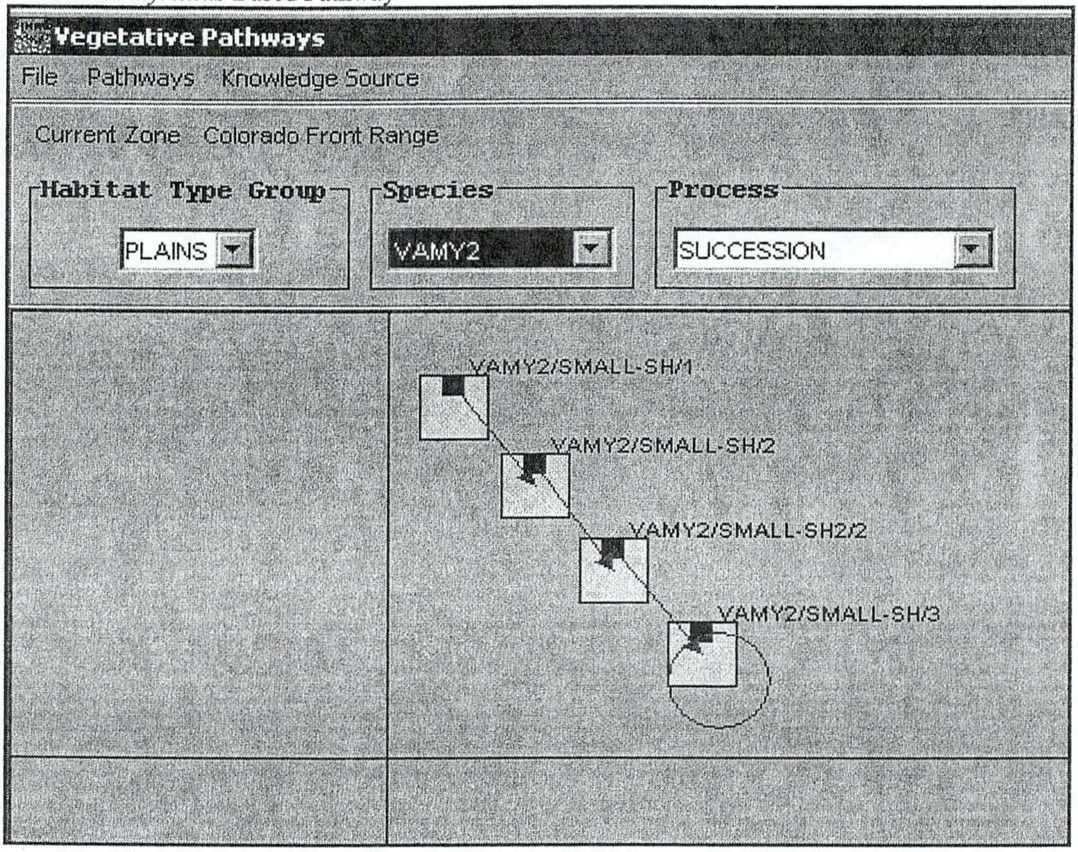
Riparian *Salix* Based Pathway



Upland *Salix* Based Pathway



Vaccinium myrtillus Based Pathway



Pinus edulis-Juniperus Based Pathway